TRANSFORMING HEALTHCARE: THE ROLE OF ENGINEERING IN DELIVERING A NET ZERO HEALTH SERVICE.

Institution of MECHANICAL ENGINEERS

Improving the world through engineering

imeche.org

“”

The NHS and other global healthcare organisations cannot make these changes alone. Engineering will and is playing a significant role in improving care provision and in developing the technology that clinicians use.

Dr Helen Meese CEng MIMechE MIPEM MWES FRSA, Chair of Biomedical Engineering Division

“”

The transition to Net Zero requires a multi-stakeholder approach, and nowhere is this more evident than in healthcare. Engineers have a huge role to play here, not only in designing and implementing sustainable healthcare solutions but also in fostering collaboration across disciplines and industries to ensure a healthier and more sustainable future for all.

Addie MacGregor
Association of British HealthTech Industries (ABHI)

For more information contact

Engineering Policy Unit
Institution of Mechanical Engineers

policy@imeche.org

Published April 2024

Authors

Dr Helen Meese CEng MIMechE MIPEM MWES FRSA

Dr Laura Kent

William Rowe

Case studies

George Cave
Apian

Ed Pennington-Ridge
Elegant Design and Solutions Ltd

Professor Ramani Moonesinghe
University College London Hospitals

Dr Tom Dawson
Revolution-ZERO

Lise Pape
Walk With Path

Acknowledgements

Professor James Barlow
Imperial College London

Professor Aneel Bhangu MBChB FRCS PhD
University of Birmingham

Joseph Burton
UCLH

Dr Chris Green MBBS BMedSci(Hons) DTM&H MRCP(ID) DPhil(Oxon)
University of Birmingham

Felicia Hedetoft
Nordic Center for Sustainable Healthcare

Dr Edgars Kelmers
Cerca Magnetics

Christopher Mariani
Cerca Magnetics

Connor McAleer CEng
T-SQUARED

Prof A. J. McGuire
London School of Economics

Chris Naylor
Centre for Sustainable Healthcare

Luella Trickett
Association of British HealthTech Industries

Addie MacGregor
Association of British HealthTech Industries

Rachel Stancliffe
Centre for Sustainable Healthcare

Members of the Environmental Sustainability Group
IPEM

Biomedical Engineering Division Committee
IMechE

Rupert Blackstone
Chair of Energy, Environment and Sustainability Group
IMechE

Maira Bana
Chair of Construction and Building Services Division
IMechE

Contents

Foreword

Over the last 100 years global healthcare provision has increased, leading to better health outcomes and increased life expectancies across many parts of the world. At the same time, our consumption of our planet's resources has grown exponentially, which has led to the emergence of an unintended threat, one that poses dangers to the health of every member of the global population. This is, of course, climate change.

The impacts of climate change on health are profound. More frequent natural disasters, pressures on food systems, and an increase in vector borne diseases pile pressure on health systems globally, exacerbating existing inequalities around the world. In the UK we are not immune to this, with increasing weather extremes already directly and indirectly impacting our population, and therefore our health services.

The recognition of this now dominating crisis has caused countries to take stock of their contributions to global climate change and develop responses, with the UK becoming the world's first major economy to pass laws pledging to end its contribution to climate change.

To achieve this, action is required across all sectors, including healthcare, which itself contributes significantly to climate change, despite its mission to maintain and improve public health.

As Europe's biggest employer and one the UK's largest landowners, the NHS is responsible for around 4% of the UK's carbon emissions. This burden was acknowledged in October 2020 when England's NHS became the world's first health service to commit to reaching carbon Net Zero, for the emissions it controls directly by 2040, and the emissions it can influence by 2045, by following the route outlined by the 'Delivering a 'Net Zero' National Health Service' report. Similar promises have since been made by NHS organisations across the UK's other nations.

Over recent years, NHS trusts across the UK have mobilised to work towards this goal, supported by Greener NHS and many other organisations, addressing all aspects of the way healthcare functions. This ranges from designing new and retrofitting existing healthcare facilities, engaging and educating healthcare professionals in sustainable healthcare practice, to working with supply chains and industry to cut emissions.

To implement these plans, meet improved standards, and discover new solutions will rely on a huge interdisciplinary effort. One discipline that touches every aspect of the healthcare's Net Zero journey is engineering. Without a significant contribution from engineers in improving existing facilities and equipment, or engineers in academia and industry working on novel solutions to complex sustainability challenges, achieving Net Zero within healthcare goal will be impossible.

This report by the Institution of Mechanical Engineers underscores engineering's role and acts as a timely and important call to arms to engineers, funders, academia, industry, and healthcare providers to join together to create an environment that supports engineering to fulfil its potential within healthcare and play a key role in achieving the NHS's Net Zero ambition.

Rachel Stancliffe
Founder and CEO of the Centre for Sustainable Healthcare

Abbreviations

Abbreviation	Definition
AAC	Accelerated Access Collaborative
ABHI	Association of British HealthTech Industries
BMA	British Medical Association
CAA	Civil Aviation Authority
CRP	Carbon Reduction Plan
DFU	Diabetic foot ulcer
DHSC	Department of Health and Social Care
DPN	Diabetic peripheral neuropathy
EDaS	Elegant Design and Solutions Ltd
FDI	Foreign direct investment
HCWH	Health Care Without Harm
IDAP	Innovative Devices Access Pathway
IMechE	Institution of Mechanical Engineers
IPCC	Intergovernmental Panel on Climate Change
IPEM	Institute of Physics and Engineering in Medicine
LDC	Less developed country
LIHE	London Institute for Healthcare Engineering
MHRA	Medicines and Healthcare products Regulatory Agency
MPCE	Medical Physics and Clinical Engineering
NAP3	Third National Adaptation Programme
NDFA	National Diabetes Foot Care Audit
NHS	National Health Service
NHSE	NHS England
NIHR	National Institute for Health and Care Research
NO_2	Nitrogen dioxide
PEI	Professional engineering institution
PM2.5	Particulate matter 2.5 micrometres or smaller
PPE	Personal protective equipment
PTP	Practitioner Training Programme
SBRI	Small Business Research Initiative
SME	Small and medium-sized enterprise
STP	Scientist Training Programme
TDA	Temporary danger area
UKCA	UK Conformity Assessed
UKRI	UK Research and Innovation
UN	United Nations
WHO	World Health Organization

Key messages at a glance

1	**Facilitating collaborative innovation in healthcare by promoting partnerships between engineers, healthcare providers, academia, and industry to develop sustainable solutions.**	To encourage and support the development of solutions within the healthcare sector and achieve Net Zero aspirations, strategic enhancement of knowledge generation and sharing mechanisms, both within and across the UK's four nations and among the NHS, academia, professional engineering institutions, patients, and industry, is imperative.
2	**Creating a supportive funding and regulatory environment to empower engineers, small and medium-sized enterprises (SMEs), and industry to tackle sustainability challenges within healthcare.**	To support the development and deployment of solutions and empower engineers, SMEs, and industry to tackle sustainability challenges within the healthcare sector, an expansion of dedicated funding mechanisms will be required, alongside an evolution of the regulatory landscape that enables innovation to flourish.
3	**Integration of engineering expertise in healthcare systems.**	To facilitate the transition to a more technologically advanced and sustainable healthcare system, it is essential for hospitals and NHS trusts to integrate engineering seamlessly into their standard practices.
4	**Industry engagement and accountability through sustainability measurements, supporting robust emission measurement and compliance monitoring.**	To tackle the largest contributor to healthcare's greenhouse gas footprint, its supply chain, industry partners and suppliers must work with healthcare providers and the government to help achieve targets relating to supply chain emissions, using realistic and robust measures.
5	**Development of a coherent government strategy linking the environmental crisis to patient care that includes plans to address climate change related impacts on health.**	To encourage the transition to a more sustainable health service and achieve relevant targets, increased public support and a broader understanding of the interconnectedness of climate change and health are required.

Executive summary

If the health sector were a country, it would be the fifth largest emitter on the planet, with a climate footprint equivalent to the annual greenhouse gas emissions from 514 coal-fired power plants. This contribution was estimated in 2019 by Health Care Without Harm (HCWC), in partnership with UK consultancy firm Arup, to be equivalent to 4.4% of global net emissions.[1]

Healthcare's substantial contribution to global climate change through its emissions seems paradoxical considering that climate change is perceived as one of the biggest threats to human health globally.[2]

HCWH defines the UK, along with many other developed countries,[3] a 'major emitter'.[1] In an attempt to address this problem, in 2020, England's National Health Service (NHS) became the world's first health service to commit to reaching 'Carbon Net Zero' and released its 'Delivering a 'Net Zero' National Health Service' report to outline how this would be achieved.[4] In 2022, this goal was embedded into legislation through the Health and Care Act.[5] Shortly after NHS England's 2020 commitment, the health services in Wales and Scotland outlined similar targets.[6,7]

The targets set by each UK nation are a positive step in correcting healthcare's course towards a more sustainable delivery system. However, coordinated action will be required on a large scale to build, refurbish, and modernise healthcare facilities, fleets, supply chains, and practices in every setting. The big challenge for healthcare comes in balancing the need to change practices with maintaining patient safety and without increasing the financial burden on stretched healthcare systems.

Engineers will be essential in delivering a Net Zero health service, both in the UK and globally, by designing, developing, deploying, and maintaining structures, machines, systems, materials, and processes to solve the challenges facing the healthcare sector.

Engineering already is and must continue to play a significant role in improving care provision and in developing the technology that clinicians use. It is then that engineers, working alongside leaders in finance, policy, and strategy roles, that can support and drive the uptake of sustainable and green technology alternatives for the healthcare sector going forward. Some of these technologies, explored within this report, are already having a significant impact on population health and well-being, yet their adoption remains limited on a large scale.

Decarbonisation of the healthcare sector is a challenge that countries around the world will need to address if the goals of the Paris Agreement are to be achieved. Less Developed Countries (LDCs) face distinct challenges in establishing sustainable healthcare systems, including securing reliable electricity and clean water supplies, and maintaining sustainable cold chains for medication and vaccinations. However, this presents an opportunity for foundational establishment of sustainable practices. The UK is in a good position to become an international leader in this space, as many look to the NHS as a model in setting Net Zero targets, reducing emissions, and technology uptake. By actively supporting the sharing of best practices and expertise across borders, the UK can contribute significantly to the global efforts to foster sustainability within healthcare systems.

However, there are many existing barriers that engineers and the engineering profession generally face when developing, testing, and deploying new technologies in healthcare systems.

This report explores the sustainability challenges facing healthcare, the positive steps taken across the UK to address them, and how engineering can and already is contributing to healthcare's Net Zero transition.

Recommendations

The Institution of Mechanical Engineers makes these recommendations that apply to the following actors across the United Kingdom's four nations. Further details can be found in the report.

Government

Departments, funders, and regulatory bodies run through central government relating to healthcare, eg. DHSC, MHRA, NIHR, Innovate UK.

Healthcare

National Health Services in England, Scotland, and Wales and Health and Social Care in Northern Ireland, and associated bodies and local providers of public healthcare.

Higher Education

Universities and institutions that are active in teaching and research relating to engineering and health disciplines.

Industry

Companies that develop and sell services relating to health and its sustainable delivery. Includes organisations from small and medium enterprises to large multinationals.

Professional Engineering Institutions

Bodies that are responsible for licensing and accrediting engineering education courses in the UK, as well as chartering engineers and promoting policy advice to government.

1. Facilitating collaborative innovation in healthcare by promoting partnerships between engineers, healthcare providers, academia, and industry to develop sustainable solutions.

To encourage and support the development of solutions within the healthcare sector and achieve Net Zero aspirations, strategic enhancement of knowledge generation and sharing mechanisms, both within and across the UK's four nations and among the NHS, academia, professional engineering institutions, patients, and industry, is imperative. Courses of action should include the following:

- Creation of opportunities for engineers in industry and academia to engage with healthcare settings and work alongside clinicians to gain a first-hand understanding of the challenges faced by healthcare providers and develop innovative solutions that directly address the unique needs of the healthcare sector. In the first case, this could involve sandpit events and workshops, following the example set by some health innovation networks, and supported by NHS trusts, Professional Engineering Institutions, and universities.

  Healthcare | Professional Engineering Institutions | Higher Education

- Creation and implementation of a centralised knowledge-exchange platform to facilitate the seamless exchange of knowledge and best practices between hospitals and industry. This will serve as an opportunity to share success stories, lessons learned, and collaborative opportunities and prevent the duplication of efforts.

  Government

2. Creating a supportive funding and regulatory environment to empower engineers, small and medium-sized enterprises (SMEs), and industry to tackle sustainability challenges within healthcare.

To support the development and deployment of solutions and empower engineers, SMEs, and industry to tackle sustainability challenges within the healthcare sector, an expansion of dedicated funding mechanisms will be required, alongside an evolution of the regulatory landscape that enables innovation to flourish. In particular the following are needed:

- Enhanced funding mechanisms, with a specific focus on sustainability challenges. Building on the Net Zero-specific initiatives led by the SBRI Healthcare programme, there is a need for more targeted calls with a focus on sustainability and increased encouragement for university involvement. Capitalising on the success of Innovate UK's Biomedical Catalyst funding, governments should consider expanding similar initiatives to further stimulate innovation.

  Government | Healthcare

- Targeted Net Zero funding for hospitals. Hospitals are under extreme financial pressures, and while there is a desire to achieve Net Zero and more sustainable healthcare systems, it is not a priority given current constraints. If governments are serious about achieving sustainability goals, targeted funding for hospitals should be prioritised to empower them to improve existing equipment and implement innovative novel technologies, guided by Net Zero boards and informed by engineers. Technologies that lead to cost savings as well as environmental and patient benefits should continue to be prioritised and promoted, to increase awareness of the advantages of innovating in healthcare. Hospitals can act as test-beds for new low carbon technologies, but this needs to be supported financially and by simple procurement mechanisms.

  Government | Healthcare

- A streamlined regulatory process and support for companies to navigate this. Use the current review of medical device regulations to work towards understanding current barriers and simplifying regulatory requirements for sustainability-focused innovations, learning lessons from the Covid-19 response and reducing the time it takes for innovations to get to market. New regulations should lower the regulatory burden while maintaining world-leading safety standards, which will be particularly beneficial to SMEs. The UK has an opportunity to develop an innovative and responsive regulatory system, and regulatory bodies should work with industry-led organisations like the Association of British HealthTech Industries (ABHI) to guide this development.

  Government

3. Integration of engineering expertise in healthcare systems.

To facilitate the transition to a more technologically advanced and sustainable healthcare system, it is essential for hospitals and NHS trusts to integrate engineering seamlessly into their standard practices.

- Facilitating engineering innovation within healthcare settings. The NHS should explore further opportunities for clinical engineers employed by the NHS to work closer with colleagues in hospitals as part of the clinical team and develop tailored solutions to Net Zero challenges. This should be supported with the provision of further roles for engineers at the decision-making level of healthcare organisations, where they can provide technical expertise and oversight to support healthcare's Net Zero transition. This is already occurring in some settings, but a consistent approach across healthcare is required.

  Healthcare

- Workforce planning in collaboration with professional engineering institutions to assess the current and future needs of clinical engineers within hospitals to support the integration of new technologies.

  Healthcare | Professional Engineering Institutions

- Promoting and enhancing pathways to biomedical engineering careers through a joined-up approach to training environmental progression. Healthcare providers should continue to develop their apprenticeship, T-level, and training opportunities for engineers and provide attractive and uniformly recognised roles across healthcare. They should be supported by professional engineering institutions, who should work with the National School of Healthcare Science to actively promote biomedical or clinical engineering as an attractive and exciting career opportunity to implement problem-solving skills in a high-impact sector.

  Healthcare | Professional Engineering Institutions | Higher Education

4. Industry engagement and accountability through sustainability measurements, supporting robust emission measurement and compliance monitoring.

To tackle the largest contributor to healthcare's greenhouse gas footprint, its supply chain, industry partners and suppliers must work with healthcare providers and the government to help achieve targets relating to supply chain emissions, using realistic and robust measures.

- Incentivising sustainability practices in the supply chain. While it is right to question the impact of supply chains as identified in the Net Zero Supplier Roadmap, it needs to be done in a considered, supported, and practical manner to ensure responsibility is not shifted down the supply chain. The NHS should continue to work collaboratively with industry representatives, such as the ABHI, to understand the underlying challenges to decarbonising the supply chain and develop consistent monitoring practices and tools across the supply chain to engagement, such as the Evergreen Sustainable Supplier Assessment.

  Healthcare | Industry

- Emission measurements and compliance monitoring. With the NHS already under pressure, consideration of effective emission measurements and compliance monitoring is needed. Ideally, robust mechanisms, involving regular assessments, audit, and reporting obligations would be implemented. The NHS should work with industry and the National Measurement Laboratories to consider the practicalities of monitoring.

  Government | Healthcare | Industry

5. Development of a coherent government strategy linking the environmental crisis to patient care that includes plans to address climate change related impacts on health.

To encourage the transition to a more sustainable health service and achieve relevant targets, increased public support and a broader understanding of the interconnectedness of climate change and health are required.

- Development of a UK-wide strategy, linking the ongoing environmental crisis to patient care, placing the environment and patient outcomes at its core. This strategy should emphasise the interconnection between climate change and health, the need for urgent solutions, and the importance of technology acceptance by patients.

  Government | Healthcare

- A public awareness campaign is essential to address the declining support and awareness of the impact of the healthcare sector on the environment and support the uptake of new technologies. This could include sharing with patients details on the carbon footprint of the care they receive.

  Government | Healthcare | Higher Education

Unsustainable healthcare

The climate change–healthcare nexus

What is Net Zero?

Put simply, Net Zero means cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, for instance, by oceans and forests.

What is sustainable healthcare?

The World Health Organization (WHO) defines an environmentally sustainable health system as one that improves, maintains, or restores health while minimising negative impacts on the environment and leveraging opportunities to restore and improve it, benefitting the health and well-being of current and future generations.[8]

The impact of climate on human health

In its Sixth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) stated that human activities have unequivocally caused global warming, a statement supported by over 99% of the climate-related peer-reviewed scientific literature.[9,10] Changes in the atmosphere of the Earth, oceans, cryosphere, and biosphere as a result of increased temperatures have transformed weather extremes across the planet. This has increased the incidence and severity of adverse weather events, threatening nature and people in every region of the globe.

During the 2023 United Nations (UN) General Assembly in New York, the WHO revealed estimates that one in four deaths can be attributed to preventable environmental causes,[11] leading Dr Vanessa Kerry, WHO's Director-General Special Envoy for Climate Change and Health, to label climate change as "the biggest threat to health in the 21st century".[2]

The effects of climate change on health are widespread (Figure 2). It can act both as a 'threat multiplier',[12] exacerbating existing dangers to human health, and also create new risks. Extreme weather events like heatwaves, floods, droughts, and wildfires lead to direct and indirect health impacts on the communities that they affect, which are often those that are most vulnerable.[9] Direct impacts include injuries and fatalities from extreme events or heat-related illnesses during heatwaves, while indirect health impacts from climate change can be attributed to reduced water quality or malnutrition resulting from a disruption to food systems after a disaster strikes.[13] Additionally, mental health challenges have been associated with rising temperatures, trauma from extreme events, and loss of livelihoods and culture.[9]

Although the effects of climate change on health are disproportionately weighted towards those countries that have contributed the least to the climate crisis,[9] its threat to human health in historically high-emitting countries, such as the United Kingdom, is also significant. During the summer of 2022, the UK's fourth hottest summer on record,[14] 2,985 excess deaths were observed, the highest since 2004 when records began.[15,16]

Another symptom of human-induced climate change is poor air quality, which the UK government views as "the largest environmental risk to public health in the UK".[17] Indeed, the number of deaths attributable to air pollution in 2019 was estimated to be between 26,000 and 38,000.[18] In 2018, Public Health England (now the UK Health Security Agency) estimated the cost of air pollution to the NHS and social care to be £1.6 billion for particulate matter 2.5 micrometres or smaller (PM2.5) and nitrogen dioxide (NO_2) combined.[19] Countries such as the UK may see further indirect effects of rising global temperatures, with scientists predicting that higher temperatures will continue to increase the incidence of infectious diseases that are usually associated with tropical countries.[20,21]

How does climate change affect health?

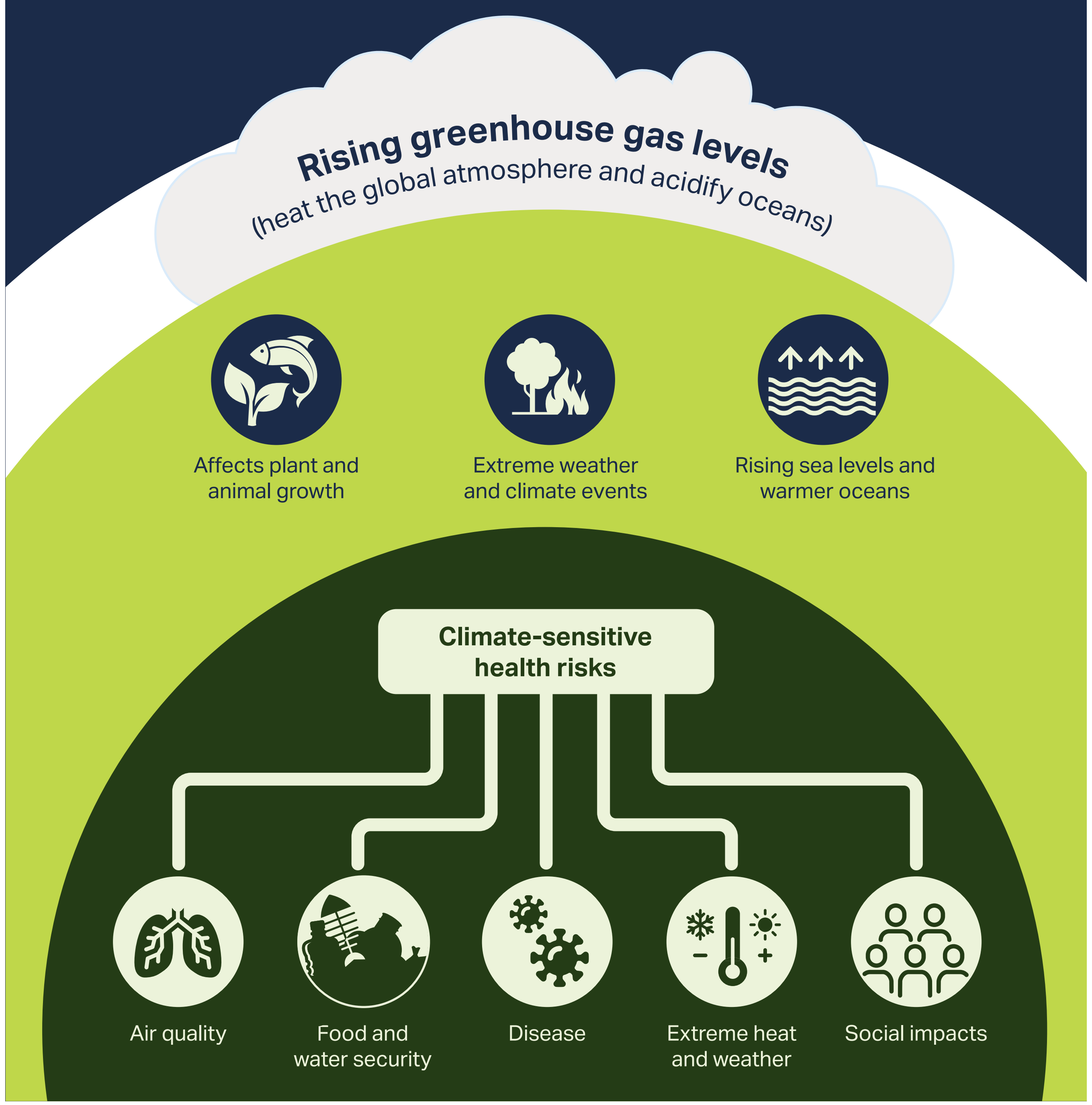


Figure 2. How climate change affects health explained. Adapted from Wellcome Trust
https://wellcome.org/news/how-climate-change-affects-health-explained

The impact of climate change on health is undeniable, both in the UK and globally. However, the IPCC provides some cause for optimism. Their 2023 report states that air quality and health in particular would benefit from deep, rapid, and sustained mitigation and accelerated implementation of adaptation actions this decade.[9] It is messages such as this that should act as a call to arms for all nations in the fight against climate change. By identifying and addressing its biggest drivers and utilising transdisciplinary collaboration, including engineering expertise, nations can catalyse rapid and meaningful change.

The impact of healthcare on climate

Given the severe threat that climate change presents to global health, it is paradoxical that a substantial contributor to human-induced climate change is the global healthcare sector itself.

In 2019, NGO Health Care Without Harm (HCWH), in partnership with the UK consultancy firm Arup, estimated that healthcare's climate footprint was equivalent to 4.4% of global net emissions.[1] This is comparable to the annual greenhouse gas emissions from 514 coal-fired power plants, and if the health sector were a country, it would be the fifth largest emitter on the planet.

The sources of the healthcare sector's emissions varied across three scopes (Figure 3):

- **Scope 1:** emissions directly from healthcare facilities and healthcare owned vehicles (17% of total emissions);
- **Scope 2:** indirect emissions from purchased energy sources such as electricity (12% of total emissions); and
- **Scope 3:** all other indirect emissions, including from healthcare's supply chain (71% of total emissions).

The UK is no exception to this pattern. Currently, emissions from the NHS alone make up 4% of England's carbon footprint,[4] and when broken down (Figure 4), this follows a similar pattern to the global estimates presented by HCWH.

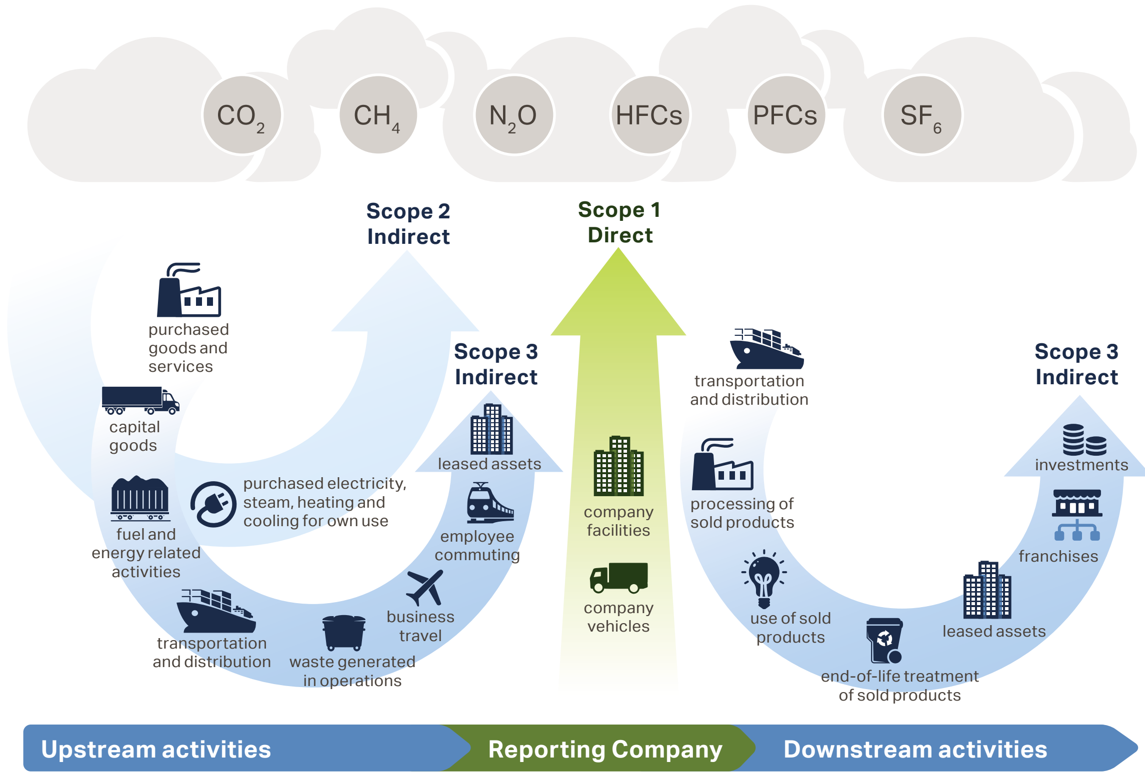


Figure 3. Overview of GHG protocol scopes and emissions across the value chain. Adapted from Greenhouse Gas Protocol.
https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf

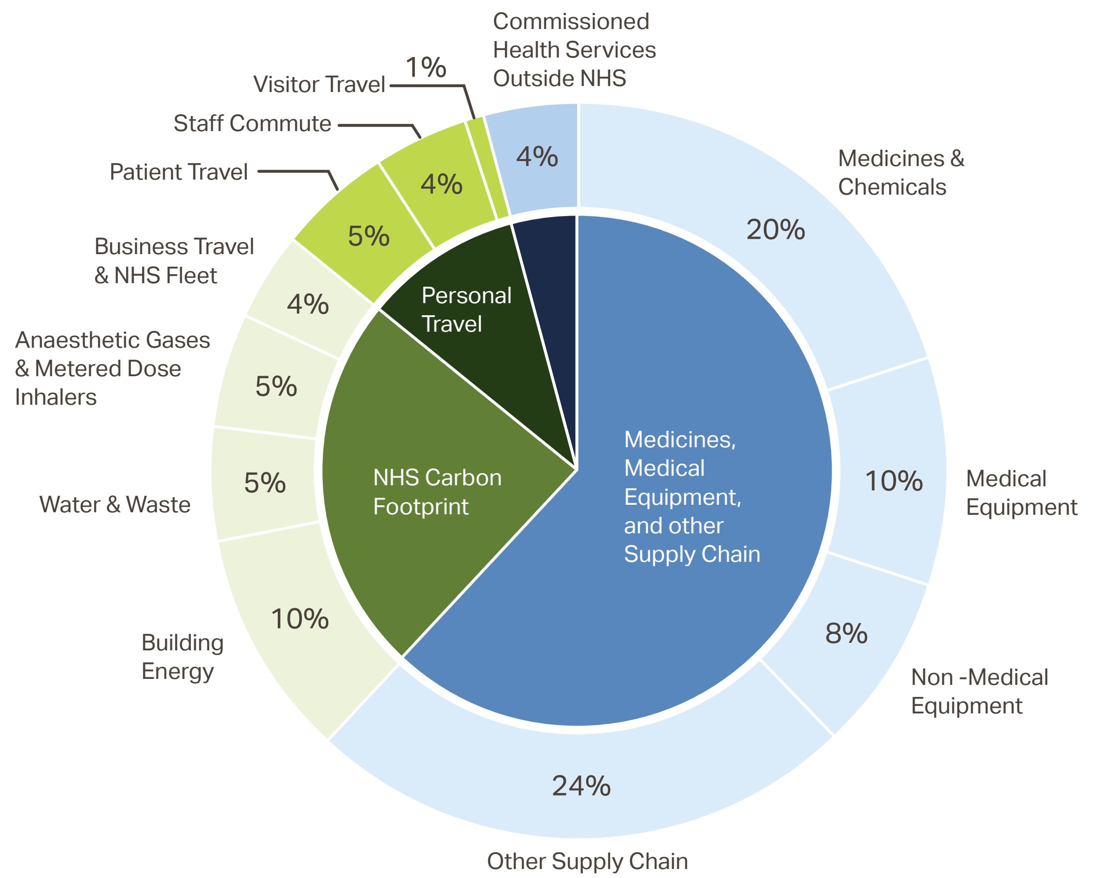


Figure 4. Sources of carbon emissions by proportion of NHS Carbon Footprint Plus. Adapted from NHS England. https://www.england.nhs.uk/greenernhs/wp-content/uploads/sites/51/2022/07/B1728-delivering-a-net-zero-nhs-july-2022.pdf

Various supply chain components make up 62% of NHS England's (NHSE's) Carbon Footprint Plus (the entire scope of NHS emissions); patient and visitor travel, staff commute, and commissioned health services outside the NHS contribute around 14%; and direct emissions from the NHS vehicle fleet, building energy, anaesthetic gases, inhalers, and water and waste make up the remaining 24% of the organisation's carbon emissions.

Focus of this report

Across all of the scopes characterised by HCWH and NHSE, there are numerous challenges to overcome if healthcare is to become more sustainable and reduce its negative impact on the climate, all of which require engineering expertise to be tackled effectively.

The challenges vary greatly depending on the healthcare setting in question, but all countries are faced with unsustainable aspects of healthcare systems. However, as it is classified by HCWH as a 'major emitter',[1] this report will focus on the healthcare systems, technologies, and associated challenges present in the UK. Many of the challenges and subsequent recommendations outlined can be applied in healthcare settings across the world, and this is encouraged since international cross-collaboration will be a key factor in decarbonising healthcare globally.

This report will outline the strategies and steps being taken by the UK's public health providers to facilitate a Net Zero transition, explore the current role of engineering in healthcare, and discuss the barriers the discipline faces to effectively contributing to this goal. It then outlines recommendations that will enable engineering to overcome these challenges and the next steps required to act on them.

Transitioning healthcare to Net Zero

In 2020, NHS England embarked on an ambitious journey outlined in the report 'Delivering a 'Net Zero' National Health Service', aiming to make the NHS the world's first Net Zero health service by 2045.[4] This was broken down into two clear targets: NHS Carbon Footprint Net Zero by 2040, which covers the emissions they control directly, and achieving Net Zero for the NHS Carbon Footprint Plus, the emissions they can influence, by 2045.

This commitment has since been echoed in Wales and Scotland. In Scotland, a Net Zero health service by 2040 target has been set and driven by the Scottish Government.[6] Scotland has also set a target of 2045 for decarbonising sources it does not control but can influence, such as the supply chain, staff commuting, and patient and visitor travel. Wales has committed to a minimum reduction in emissions of 34% by 2030 to meet the wider goal of a Net Zero public sector by 2030.[7] Notably, Northern Ireland has yet to establish a specific target, although it did join the 2021 commitment to become Net Zero and build climate resilience through the COP26 Health Programme.[22]

The NHS has made substantial progress in becoming more sustainable and less carbon intensive, with various initiatives implemented at both the organisational and national levels. England, for instance, witnessed a reduction in its NHS Carbon Footprint Plus (emissions the NHS can influence rather than control) from 27.3 $MtCO_2e$ in 2015 to 25.0 $MtCO_2e$ in 2019.[4] However, an analysis by the British Medical Association (BMA) found that reporting is inconsistent across the country, and where calculations have been carried out, the data indicate a slowdown in progress.[23]

Efforts to make practices more sustainable have included measures such as reducing the number of petrol and diesel vehicles in NHS fleets, adopting sustainable lighting, and incorporating renewable energy sources.[4] Some trusts have made further progress than others by employing dedicated staff, upgrading building efficiency, switching to renewable energy, and changing procurement practices.

However, there are challenges in advancing beyond these initial achievements. Without dedicated funding, significant strides towards a sustainable healthcare system might be hindered, particularly considering the substantial pressures NHS organisations are under. The desire and willingness are there, but funding is desperately needed to catalyse significant improvements.

Consistent measurement and reporting of carbon emissions is critical for assessing progress. One-third of NHS organisations that responded to the BMA survey reported not measuring their carbon emissions, highlighting the need for universal monitoring practices.[23] National guidance, standards, and tools related to carbon monitoring and training support could standardise practices across the NHS, fostering fair comparisons and encouraging collective action towards achieving Net Zero targets.

Net Zero healthcare: A global opportunity for the UK

The UK's healthcare facilities and practices have been continually developed over the last seventy-five years, with many hospitals being constructed before the NHS's creation in 1948.[24] Many of these are using medical devices that are now considered outdated.[25] Economic pressures limit the number of new hospitals the NHS can build, meaning that decarbonisation strategies must focus on the significant existing stock and technologies used within them, where there are the most gains to be made. This includes how hospitals receive energy, how existing medical devices and equipment are managed and upgraded, and how waste is treated. For example, when considering how healthcare facilities are heated, the Scottish Government issued a policy for NHS Scotland that sets a target that all NHS-owned buildings in the country must be heated by renewable sources by 2038 or earlier,[26] which in most cases will require replacement of the current heating system used.

The challenges faced by less developed countries (LDCs) in building sustainable healthcare systems are very different from those faced in the UK. This includes consideration of how hospitals can secure a reliable electricity supply, a clean water supply, and how they can guarantee the existence of sustainable cold chains for medication and vaccinations.

However, it could be argued that the lack of these features could enable such nations to establish sustainable practices at a foundational level rather than adapting what is already there, as the UK must do.

The UK, with its depth of knowledge and experience in how both sustainable and unsustainable healthcare practices operate, is in a unique position to support LDCs in developing sustainable healthcare systems. By being an international leader in transitioning its healthcare systems to Net Zero emissions, the UK can act as a model country in sustainable healthcare practices and deploy its world-leading experts to address the engineering challenges faced in different healthcare settings across the world.

> "The UK is leading sustainable healthcare research, from new plastics technologies through to testing reusable drapes and gowns in the major DRAGON randomised trial. This research will influence NHS practices, and rapidly disseminate outside of UK borders."
>
> **Aneel Bhangu**
> Professor of Global Surgery at the University of Birmingham

The engineering response: How will engineers meet the challenges posed by Net Zero healthcare?

In 2019, the UK became the first major economy to enshrine its Net Zero commitments into law, committing to the ambitious target of bringing all greenhouse gas emissions to Net Zero by 2050.[27] Reaching this goal, integral to the achievement of the objective set out by the 2015 Paris Agreement to limit global warming to 1.5°C above preindustrial levels, relies on the expertise of many disciplines, including engineers.[28] Technical knowledge and the ability to deploy systems approaches make engineers indispensable assets in arguably the most ambitious engineering project ever undertaken.

The expertise of engineers will be relevant across all sectors in the Net Zero transition, not least within healthcare, where an abundance of opportunities exists for engineers to have a positive impact, from the smallest single-use devices for testing and surgical applications to the vehicles driven by emergency responders. The IMechE has highlighted the engineering community's willingness and potential to make a difference by highlighting 'Healthcare and infectious disease control' as one of its four key policy priorities within its 'Strategy 2030'.[29]

This section of the report will explore the broad areas through which engineering can contribute to a Net Zero healthcare system, particularly in the UK, before considering the biggest challenges that must be overcome if this goal is to be achieved. Finally, it will showcase inspiring examples of engineers and innovators who are already facilitating the transition to a Net Zero healthcare system.

Healthcare problems require engineering solutions

The potential for engineers to contribute towards a Net Zero healthcare system is vast, encompassing a range of direct actions. Some of these are explored below.

Estates and facilities

The operation of NHSE's facilities contributes 15% of its 'Carbon Footprint Plus', 10% of which comes from providing buildings with energy.[4] To address this, NHSE has published its 'Net Zero Building Standard', which outlines the performance criteria relating to various elements of Net Zero carbon building for NHS construction and renovation projects.[31] Engineering innovations are essential to support the building of new Net Zero hospitals and renovation projects that follow the standard. This includes insulating, lighting, air conditioning, ventilation, and hot water solutions, all of which will also be vital in retrofitting existing healthcare facilities. Importantly, this also includes how energy and heat are generated for hospitals and where different renewable or low-carbon technologies can be beneficial for certain facilities. For example, where local opportunities exist, such as geothermal or nuclear, they must be considered. The NHS predicts that the majority of sites will require a 'dominance' of heat pump technologies, supported by renewable electricity and battery storage when demand is high.[4] However, a significant threat to the heat pump industry as a whole is a lack of skilled engineers, something that will need to be addressed for the NHS to cut emissions from its new and existing facilities.[32] The role of engineers in transitioning NHS facilities is further underlined in the Net Zero Building Standard's key roles, where they are named under the 'Designers' role, and they are responsible for much of the design and compliance aspects of building and renovation work.

“”

Clinical Engineering is a speciality within biomedical engineering responsible primarily for applying and implementing medical technology to optimise healthcare delivery.

Clinical engineering is a scientific discipline with a wide scope, offering diverse job roles that make significant impacts on patient care. Many engineers have patient-facing roles operating in areas where there is a high degree of data complexity such as gait analysis, urodynamics or rehabilitation engineering. Many others have system-level roles controlling the flow of medical equipment within the hospital, influencing clinical service design and developing clinico-technical innovations. A few work in the area of novel device design. Many clinical scientists in engineering will lead research or support the research of others as part of their job profile.

National School of Healthcare Science[30]

Adapting hospitals to heat

It is estimated that 90% of the UK's NHS hospital buildings are vulnerable to overheating, even during moderately warm summers.[33] As the incidence and intensity of heatwaves increases in the UK, the potential for impact on healthcare delivery is substantial. This was showcased during the 2022 summer heatwave, when one-fifth of UK hospitals cancelled operations,[34] with unsafe theatre environments a key factor behind this. Overheating is considered in the Net Zero Building Standard, and the Third National Adaptation Programme (NAP3) pledges to support NHS trusts in incorporating climate change adaption within their Green Plans by 2027.[35] Engineers will be vital for ensuring that the design and construction of new and retrofitted hospitals consider how to incorporate passive and sustainable cooling systems alongside Net Zero features.

Travel and transport

Transportation contributes notably to healthcare's carbon footprint, both in the UK and abroad. In a 2021 survey conducted by the BMA, it was found that an average of 83% of vehicles in the NHS fleet use petrol or diesel, 8% are hybrid, and 9% are electric.[23] Around 14% of NHSE's total emissions come from road travel, both directly from its fleet and from staff and visitor travel.[4] To reduce this contribution, it is essential that the balance of the NHS's fleet is moved towards electric vehicles, a strategy promised in both NHS England's and Scotland's Net Zero Strategies,[4,6] with NHSE providing specific targets in late 2023.[36] For many vehicles present in the service, this is achievable, but as outlined in the IMechE's 2023 report on the automotive industry, it will require significant charging point rollout to become a reality.[37] To facilitate such a transition, specialist engineers are needed to maintain an electric vehicle fleet and develop innovative solutions to challenges, such as that posed by the electrification of ambulances.

While the electrification of the NHSE's fleet is a key step towards Net Zero healthcare in England, patient and visitor travel, which is outside of NHSE's direct control, contributes 6% of total emissions to its Carbon Footprint Plus.[4]

A 2019 study by independent statutory body Healthwatch found that driving is the most common mode of transport for people travelling to appointments in England,[38] and it is often the only realistic option for patients. Reducing the need for patient and staff travel through telemedicine could have a positive impact on emissions while making services more accessible,[39] but in the case of remote digital care, this can also present risks.[40] The healthcare sector will benefit from improved infrastructure for public transport and active travel as all sectors transition to Net Zero.

Supply chain

Decarbonising the supply chain is the largest obstacle facing most nations looking to improve the sustainability of their healthcare systems. However, providers are generally able to use their purchasing power to bring about change. This will require specific engineering innovations, depending on the devices, procedures, or processes in question, alongside a consistent, system-wide approach to monitoring and reporting emissions. Specific ways in which engineers are already tackling emissions within healthcare's supply chain are explored later in this report.

Waste management

In England, the NHS produces around 156,000 tonnes of clinical waste annually, in addition to other waste not deemed to be 'clinical'.[41]

In 2023, NHSE published a strategy to tackle this issue, which it predicts will save approximately £11 million each year in recurrent revenue costs and 30% of carbon emissions generated from the current waste system, which largely relies on the high-temperature incineration of waste.[41] Engineering solutions that enable reprocessing and reuse of medical equipment, clothing, and devices can play a significant role in reducing costs and emissions in this difficult-to-tackle sector.

Medicines and medical devices

A combined 30% of the NHS's Carbon Footprint Plus is attributed to medicines and medical equipment (20% and 10%, respectively).[4] Inhalers (3%) and anaesthetic gases (2%) make notable contributions to the Carbon Footprint Plus for NHSE. Innovations that utilise different medicine delivery mechanisms in inhalers and that can capture, reuse, or destroy nitrous gas used in anaesthesia are underpinned by engineering principles.

The reuse and remanufacture of medical equipment can help to transition healthcare away from a heavy reliance on single-use devices, and engineers will be important in identifying the most sustainable methods for decontaminating and remanufacturing devices, such as catheters and surgical instruments.[42,43] In addition to reducing carbon emissions and the volume of single-use waste in the NHS, such processes can also reduce the reliance on the supply of raw materials and components, an issue highlighted by trade restrictions resulting from the war in Ukraine and the recent shipping crisis in the Red Sea.[44]

Engineering's wider impacts

Additionally, engineers play a crucial role in designing and implementing solutions that promote and improve public health, including efficient sanitation systems, technologies for clean water access, and designing infrastructure to mitigate environmental hazards and ensure clean air. Engineers contribute significantly to reducing the burden on healthcare systems and fostering a healthier society overall.

Across all engineering challenges faced in transitioning healthcare to Net Zero, there is a difficult balancing act present. When we invest in new technologies, there is an initial increase in emissions through their supply chain, manufacture, and waste, contributing to the climate crisis overall and thus exacerbating health problems. Therefore, the relative costs and benefits of any option must be considered before engineering solutions are deployed, as well as where we can align actions between sectors. It is when making such decisions that collaboration between engineers and other disciplines including experts in science, public health, strategy, policy, and finance, will be vital.

Engineering in action:
How innovative engineers are making a positive difference

Engineers across the NHS are integral to keeping the health service functioning through the constant monitoring and maintenance of essential medical equipment, medical gas supplies, and the heating and ventilation systems that support hospitals.

The number and skillsets of engineers who work in healthcare settings require evaluation if the NHS is to achieve its Net Zero ambitions, a suggestion explored later in this report. Additionally, on top of these 'day-to-day' functions, engineers can develop innovative solutions to some of healthcare's most challenging sustainability questions to help improve the greenhouse gas emission profile of healthcare in the UK.

Inspiring examples of such solutions, supported by grant funding from UK government-supported initiatives, such as the Accelerated Access Collaborative (AAC)-backed Small Business Research Initiative (SBRI) Healthcare,[45] have been profiled within this report. These case studies serve as an example of the impact that engineers can have when they work alongside healthcare professionals to tackle some of the biggest sustainability challenges facing the sector.

Case study 1

Case study 2

Case study 3

Case study 4

Case study 1

Apian
Faster deliveries to more patients with fewer emissions

What problem was faced?

Approximately 3.5% of road travel in England is related to the NHS, a figure equivalent to 9.5 billion miles. This contributes to around 14% of NHS England's Carbon Footprint Plus.[4]

A proportion of these road miles come from the delivery of critical and patient-specific medical supplies, such as chemotherapy drugs, pathology samples, and antibiotics. Often, the patient-specific nature of such supplies means their delivery is difficult to plan for, leading to the use of high-emitting vehicles, which can include taxis. Urgency means that medicines and medical supplies can be transported alone, with the delivery potentially taking up the same road space and contributing a similar scale of emissions that a full delivery vehicle would.

What is the engineering innovation?

A solution to this problem has been pioneered by healthcare logistics company Apian, which uses drones to reduce the reliance on road transport when delivering medicines, devices, or blood to patients.[46]

Apian is closely linked with the NHS, originating from the NHS Clinical Entrepreneur Programme,[47] and received funding from the NHS-backed SBRI Healthcare programme in 2023.[48] Since 2020, Apian has developed a software platform that connects hospitals and trusts across the NHS to a network of drones to deliver supplies. This aims to simplify the complex network of healthcare logistics and provide a platform that allows clinicians to place orders for medications, clinical items, or sample transport and efficiently organise their delivery through a drone operator.

In recent years, Apian has proven this concept in multiple settings:

Isle of Wight trial, the world's first chemotherapy flight by drone: Cancer patients in the Isle of Wight are dependent on mainland UK for a range of chemotherapy medicines. Traditionally, this relied on a combination of ground couriers, ferries, and taxis to deliver treatments from Portsmouth to St Mary's Hospital on the island. The potential for disruption along this route is significant, which, due to the short shelf-life of chemotherapy drugs, can lead to wasted supplies. Using drones to transport these drugs reduces the four-hour end-to-end journey to as little as 30 minutes, saving staff time and minimising waste.[49]

Northumberland drone trial: Between February and May 2023, Apian partnered with the Northumbria Healthcare NHS Foundation Trust to deliver oncology pathology samples for analysis, medical devices, and medical posts. This trial demonstrated the ability of drone delivery to reduce the time pressure on teams to take samples at rural hospital sites and deliver them by ground transportation while lowering the Trust's carbon footprint.[50]

Impact

So far, much of Apian's work has focused on proving that drones can safely fly sensitive materials, such as medications, pathology samples, and blood packs. This has been achieved with a high degree of success across all projects, all while providing on-demand delivery that leads to 94–98% lower CO_2 emissions than standard ground transport.[51] This near total elimination of delivery carbon emissions is possible due to three factors: electrification, which is difficult to achieve across an existing ground healthcare delivery fleet; direct flight paths, reducing the distance travelled for delivery; and minimal energy use, with drones requiring far less energy to carry out the same delivery as even electric cars or vans.

During Apian's 2023 Northumberland project, drones flew a total of 11,267km, spending 120 hours in the air. During this relatively short project, 1480kg of CO_2 emissions savings would have been possible through drone delivery compared with normal delivery routes.

Further benefits from the Apian platform are expected, such as a reduced burden on staff through the integration of on-demand delivery into clinicians' existing workflows; a reduction of vehicles on the road, leading to reduced congestion in cities; and the use of stock centralisation to minimise waste and cut trusts' costs by allowing them to bulk purchase and ship products.

Challenges

The main challenges faced by the Apian team are related to regulation and public acceptance. Aviation regulation is currently being developed to allow the integration of drones into the UK's airspace, in line with the Airspace Modernisation Strategy,[52] as while the sky is less congested than the roads in the UK, competition for use and risk of collision can present problems.

Apian has engaged extensively with the Civil Aviation Authority (CAA), which regulates civil aviation in the UK, to plan each of its projects. This has led to the introduction of temporary danger area (TDA) airspace closures on previous projects. Applications for airspace closures have led to complaints from others using the airspace,[53] which have been addressed through engagement with the local aviation community and subsequent adjustment of the TDA. Balancing safety in a shared airspace will be key to implementing this engineering innovation within the NHS.

What are the next steps?

After proving that drones can successfully deliver blood, chemotherapy drugs, and medical devices, the next step and challenge that Apian faces is growing the NHS's drone delivery network. This will involve further trials in Northumberland in 2024 to build on learnings from the first trial.

Apian hopes that further proof that drone delivery in healthcare can be successful will lead to an increase in the number of participating trusts across the UK, which it hopes will lead to patient, staff, and climate benefits everywhere.

Case study
2

Path Feel
Prevention of foot ulcers to reduce patient travel and clinical waste

Telemedicine, the practice of using telecommunications technology to remotely diagnose and provide therapeutic interventions to a patient, could provide huge carbon emission savings for healthcare. This is primarily through a reduction in transport-related emissions, which currently make up 14% of the NHS's Carbon Footprint Plus, with patient travel responsible for around a third of this.[4,39] The ability of engineering innovations to remotely diagnose patients, ideally to prevent them from developing a condition in the first place, is the concept pioneered by Walk With Path through the development of its Path Feel insoles.[54]

What was the problem faced?

Diabetic peripheral neuropathy (DPN) is a common symptom associated with diabetes mellitus.[55] Damage to blood vessels through high blood glucose levels in diabetic patients can lead to nerve damage, which results in a loss of sensation, particularly in bodily extremities such as the feet. This leaves patients experiencing DPN at high risk of foot damage. For example, they may not notice an open wound due to stepping on a sharp object or a blister caused by poorly fitting footwear. The lack of awareness of this damage can quickly lead to the blister worsening and potentially developing into a diabetic foot ulcer (DFU), the lifetime incidence of which could be as high as 25% among diabetes patients.[56]

Due to the nerve damage already existing in a patient with DPN, ulcers can take a long time to heal, with only 50% of ulcers healing within 12 weeks.[57] A severe outcome of a DFU is foot amputation, and DFUs are one of the main causes of non-traumatic lower limb amputation worldwide.[58] In England and Wales, the National Diabetes Foot Care Audit (NDFA) 2021 found that almost one in five patients presenting with a severe ulcer were either dead or had undergone amputation within one year.[59] Indeed, the five-year mortality rate for patients with a DFU is 30%, rising to 56% for patients who have undergone a major amputation.[60,61]

As well the significant personal and health risks for patients who develop DFUs, the cost to the healthcare system and associated environmental impacts are also great. One environmental impact relates to check-ups and wound redressing, which occur multiple times per week throughout the treatment process.[61] In 2019, it was estimated that the healthcare cost of DFUs approaches £1bn per year for NHSE.[62] Regular trips to a clinician to redress wounds also contribute to the NHS's patient travel carbon footprint, which makes up 5% of the organisation's Carbon Footprint Plus.[4]

What was the engineering innovation?

The NDFA report found that catching DFUs early is key to preventing severe ulcers and improving 12-week outcomes,[59] which will lead to reduced pressure on trusts and less NHS-related traffic on the roads. Walk With Path's Path Feel insoles act on this and help to prevent DFUs from occurring in the first place.

The insoles detect elevated plantar pressure and temperature and provide feedback through an app. They also provide haptic feedback to the feet to improve walking, as balance is hindered and the risk of falling is also increased in DFU patients. The app informs users when high pressure has been detected on a specific part of their foot, prompting them to check their feet and resolve the issue. Temperature checks sense areas of inflammation and can identify potential DFU risk areas before they develop. Additionally, the app connects patients to a dashboard that their clinicians can also access, creating an open communication channel between patient and clinician, thus reducing the need for patient travel for face-to-face visits.

Impact

The end goal of Path Feel is to reduce the incidence of DFUs and thus reduce NHS-associated travel and use of disposable wound dressings. Since its invention, Path Feel has been tested extensively, with a host of benefits realised. These include carbon savings, clinical benefits for patients, and even promising health economics data. With preliminary data used in a draft health economic model, it was found that for every £1 spent on the solution, £20 will be saved by the NHS trust in which it is used.

Challenges

The main challenge faced by Walk With Path, as well as by many other innovative companies looking to positively impact healthcare, is funding. The costs associated with prototyping and efficacy studies are very high, particularly as timeframes are long. The NHS's funding model is such that even when a product like Path Feel passes multiple rounds of testing and funding, its uptake is by no means guaranteed. Lower-value procurement is controlled at the trust level, and funds are correctly placed under a high level of scrutiny. Therefore, the continuous challenge for small companies such as Walk With Path is to secure funding for the next stage of development, hopefully to bring their innovations to market.

This challenge is reflected in the findings of the SBRI evaluation, which identified a 'lack of clear guidance on how to achieve the clinical validation required for adoption into the NHS' and 'complex and bureaucratic procurement systems' as reasons that companies can have success in the competition but still find adoption into the system a challenge.[63]

What are the next steps?

In recent years, Walk With Path received Phase One funding from SBRI Healthcare. This initial funding allowed for proof-of-concept trials to take place, which were a success. The next stage for the company will be to undertake further funding cycles with SBRI Healthcare, with the goal of roll-out across the NHS.

Case study 3

Envirolieve
Cutting nitrous oxide emissions in healthcare

What problem was faced?

Anaesthetic gases contribute towards 2% of NHS England's carbon footprint,[4] 75% of which comes from nitrous oxide,[64] a powerful ozone-depleting gas that persists in the atmosphere for over 100 years.

Nitrous oxide has two primary uses in healthcare:

i) alongside other drugs to provide general anaesthesia and

ii) as an analgesic, when it is combined with oxygen to form 'gas and air', commercially known as Entonox.

In both these uses, a high concentration of nitrous oxide is expelled straight into the surroundings.[65] Nitrous oxide used in healthcare is generally stored in 'manifolds', a collection of large cylinders containing the gas that is connected to a system of pipes that supplies rooms in a facility. These manifolds and associated pipe networks have been shown to be prone to leakage, with the National Nitrous Oxide Project showing that nitrous oxide waste averages 95% across nitrous oxide manifolds at 16 sites.[66]

Nitrous oxide emissions could be markedly reduced by reviewing its use in anaesthetics and by decommissioning existing manifolds and replacing them with local cylinders. Anaesthetists have already dramatically reduced how much nitrous oxide is used for general anaesthesia, as there are alternative options that do not disadvantage patients. However, reducing Entonox use further is much more difficult. Entonox is used across a range of medical procedures, particularly for women in labour. As Entonox is safe and relatively non-invasive, it is the most popular form of pain relief used in maternity care, including for home deliveries. There are currently no reasonable alternatives for this use case.[67,68]

To achieve the reductions necessary to reduce the environmental harm associated with nitrous oxide and achieve the NHS Net Zero ambition for anaesthetic emissions, Entonox's mechanism of use by patients must be evaluated. Elegant Design and Solutions Ltd (EDaS), a company that uses engineering approaches to design sustainable solutions to a range of humanitarian challenges, has looked to address this.

What is the engineering innovation?

During the Covid-19 pandemic, large supplies of oxygen were used by ventilators supporting patients who were severely ill with the virus. Much of this oxygen was expelled by patients as they breathed out, going to waste in the surroundings, contributing to local supply issues arising from massively increased demand. As part of a team led by Martin Stanton, a UK diving rebreathing expert, Ed Pennington-Ridge, founder of EDaS, helped develop a rebreathing device for recycling oxygen in a patient's exhaled breath, greatly reducing oxygen consumption in hospital wards.

This work inspired Ed to apply this technology to nitrous oxide mitigation, and he developed a device called Envirolieve™. Envirolieve first 'primes' the user with Entonox before switching to a rebreathing device to maintain the supply and prevent losses into the surrounding environment.

Impact

The scale of Entonox use across the NHS is so great that EDaS predict that Envirolieve™ could reduce the health service's greenhouse gas footprint by at least 1%. Such an impact from a single device is unprecedented and should, with the help of alternative mitigations like cracking technology, make Entonox manifolds in hospitals a feature of the past.

Challenges

Rebreathing devices are widely used in hospitals, meaning Envirolieve™ does not receive the level of scepticism other new medical devices may encounter and will require little training for use. Such insights have been provided to the engineers at EDaS by healthcare experts such as Professor Rob Sneyd, Emeritus Professor of Anaesthesia at the University of Plymouth, and anaesthetist and intensive care doctor Professor Ramani Moonesinghe OBE, Professor of Perioperative Medicine at UCL as well as Ed's business partner and wife. Combining the knowledge and skillset of healthcare professionals and engineers was valuable in the creation of

Envirolieve™ and provides an inspiring example of how cross-disciplinary collaboration can rapidly lead to ground-breaking developments.

Some technical challenges were posed by the design of Envirolieve™. Initial trials showed that the rise time of nitrous oxide was slower than anticipated, meaning a normal rebreathing device would be ineffective. To counter this, Envirolieve™ first primes the patient to a nitrous oxide level of 40%, after which it then switches over to a rebreathing mechanism. This is a novel system and uses mechanical controls, without a need for electronics.

The route to market for Envirolieve™ seems to be well established. The main obstacles left to overcome are regulatory, which all new medicines and medical devices must pass to enter the market. These can take many months or years to navigate. A fast-track system, such as the one that was in place for medical devices during the Covid-19 pandemic, could be implemented for solutions that tackle urgent environmental problems, such as Envirolieve™. Healthcare professionals are calling for the climate emergency to be treated as a healthcare emergency, strengthening this argument.[69]

What are the next steps?

So far, EDaS has received two SBRI Healthcare grants for this work, initially to design a prototype and then to scale up production and testing. The rapid success of Envirolieve™ and the appetite of the NHS and industry to reduce nitrous oxide waste makes it likely that Envirolieve™ will be used across the health service within the next few years. In fact, EDaS has been able to partner with NHSE's main Entonox supplier, BOC, to plan for Envirolieve™'s roll out.

Case study 4

Revolution-ZERO
Tackling single use textiles using a zero waste process

What problem was faced?

Medical equipment, including regulated medical textiles, makes up a tenth of NHS England's emissions according to its Carbon Footprint Plus.[4] The impact of healthcare's reliance on single-use equipment in particular was perhaps best highlighted during the Covid-19 pandemic. Between April and September 2020, the production, transport, and waste treatment of face masks is estimated to have resulted in an additional 2.4–5.7 million tonnes of carbon dioxide being emitted across the EU, with a further 1.5 million tonnes from single-use gloves.[70] In England, one life cycle assessment found that personal protective equipment (PPE) used in the first six months of the pandemic led to the release of 106,478 tonnes CO_2e, nearly 27,000 times the average person's carbon footprint over a six-month period.[71,72]

What is the engineering innovation?

These estimates provide an indication of the threat posed by single-use medical textiles to creating a sustainable healthcare system, causing the NHS to highlight such materials as an area for concern in its Net Zero plan, with made-for-reuse medical equipment suggested as a solution.[4] Revolution-ZERO has been addressing this gap by utilising circular economy principles to displace single-use textiles with even safer, reusable alternatives that make an immediate impact across healthcare systems.

Revolution-ZERO has engineered a circular system for the design, manufacture, processing, repurposing, and recycling of medical textiles, ranging from sterile gowns and surgical drapes to masks, workwear, and linen. In April 2023, Revolution-ZERO deployed its first Net Zero targeted reprocessing facility, a ZERO-DECON unit, at St Michael's Hospital, Cornwall, which started processing surgical textiles for orthopaedic operating theatres in June 2023 for a proof-of-concept study.[73]

These ZERO-DECON units integrate Revolution-ZERO's reprocessing technologies, including digital frameworks, tracking systems, training, compliance, assurances, and modular decontamination. They can be installed in 2–3 days, allowing for rapid scaling across multiple sites and easy extension or relocation depending on demand requirements. Work has also been ongoing on the development of validated low-temperature decontamination processes and reusable sterile packaging capabilities.

Impact

During 2023's inaugural roll-out of a ZERO-DECON unit, single-use textiles were replaced by Revolution-ZERO textiles that had been co-designed with clinicians and adopted by 10 surgical teams at St Michael's Hospital. They were utilised in 100 large-joint replacement surgeries from June to November in that year.

Feedback from clinicians was positive, as were the environmental impacts of the trial. An ISO 14040 life cycle analysis completed by the UCL Bioengineering Life Cycle Analysis team modelled savings of more than 20kg CO_2e per operation, and a waste audit performed on-site found that 3kg of waste per operation was prevented.

The Revolution-ZERO model also has the potential to provide considerable financial savings for NHS trusts, both directly and through minimising waste, storage, and logistics costs. The textiles, which are registered to be used up to 75 times, also provide supply chain security through local processing and improved functionality, with the potential to be manufactured with added features depending on clinical needs.

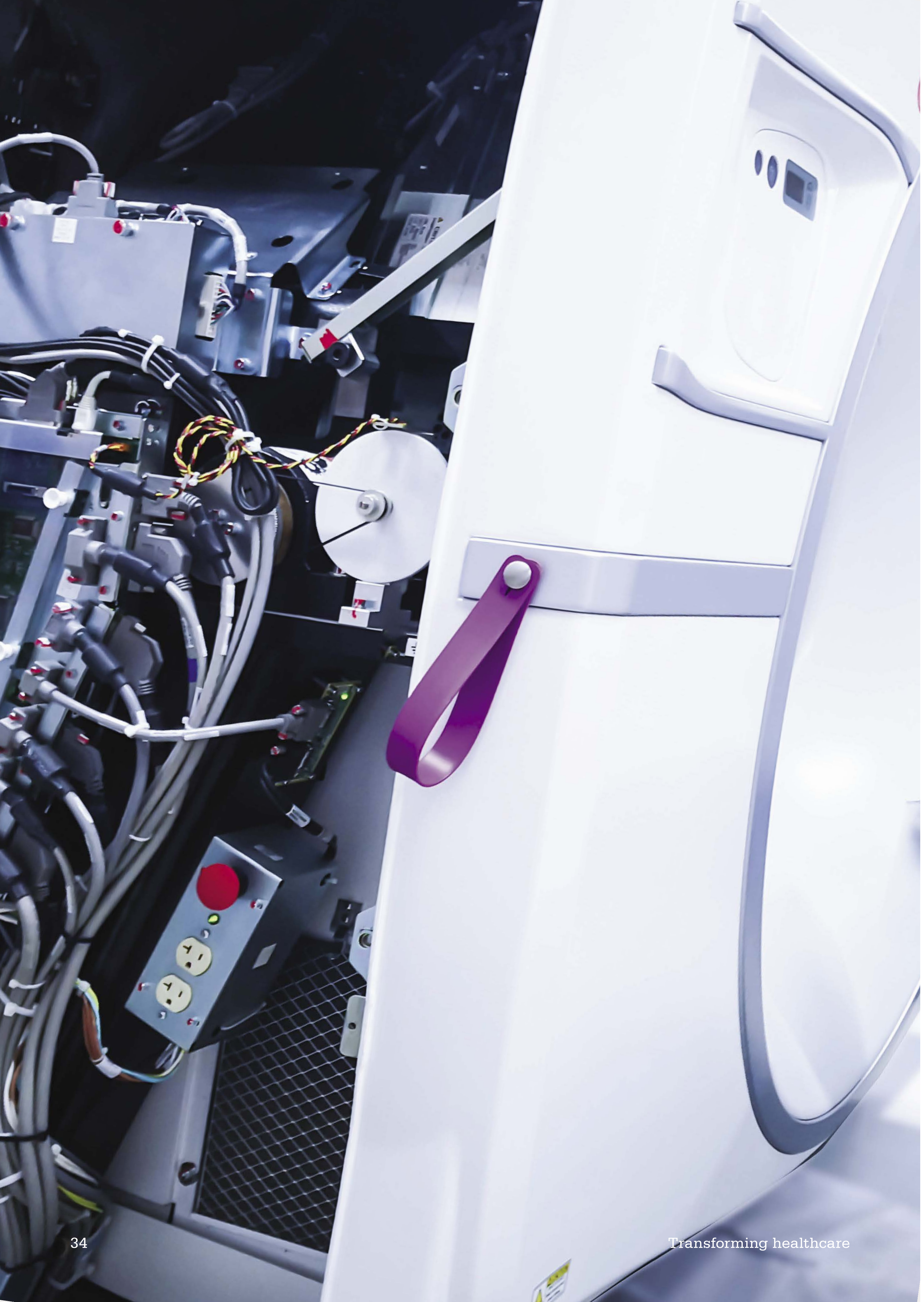
Challenges

Decades of reliance on a single-use model within healthcare systems presents product, infrastructure, logistics, procurement, culture, and workflow challenges. In addition, regulatory compliance and the required physical reprocessing infrastructure were potential problems for Revolution-ZERO, which has worked with multiple NHS trusts, universities, and other partners across the UK to address these challenges.

The modular approach of Revolution-ZERO tackles one of the most significant barriers: the lack of infrastructure available for reprocessing textiles in the UK. The ability to quickly roll out decontamination units on demand provides healthcare systems with a method to rapidly transition to this circular economy-based approach.

What are the next steps?

Revolution-ZERO is now raising further investor funding to scale and spread. It has considerable NHS engagement, including SBRI Healthcare awards, and is continuing to develop its technologies related to the validation of decontamination and low-temperature wash programmes.



Challenges facing engineering in achieving a Net Zero healthcare system

Despite early successes in implementing their green initiatives, there remain several barriers for the health systems across all four UK nations that require significant input from the engineering community if they are to achieve and maintain their long-term sustainability goals.

Funding and procurement

Funding for engineering innovators

Once any company or innovator has a novel idea, one of the first obstacles that they encounter is funding its development. Funding technical innovations within healthcare is no different, with huge competition and finite funding sources meaning that many ideas never make it past the conceptual stage.

This is evidenced by the application success rates seen in two popular healthcare funds for SMEs, Innovate UK's Biomedical Catalyst and the NHS-backed SBRI Healthcare. In the Biomedical Catalyst's 2022 Industry-led R&D awards, the success rate for applicants was 14%.[74] The story was similar in SBRI Healthcare's 2020/21 Phase 1 funding programme, with only 13% of applicants receiving funding.[75]

There are multiple public funding routes available for engineering SMEs or individuals looking to develop a solution to the NHS's sustainability crisis, which are outlined in the NHS-backed AAC's 'Health Technology Pathway: Navigation tool for Innovators in England'.[76] However, the requirements for each differs greatly and may not suit particular applications. For example, some solutions presented within this report are ineligible for many grants, as they are not medical devices, despite having potential to contribute considerably towards healthcare's journey to Net Zero.

Funds that run competitions focusing on Net Zero solutions have seen rapid success, such as SBRI Healthcare, funded through the AAC, which has run three Net Zero themed competitions since the NHS launched its Greener NHS campaign in 2020.[77] Such competitions place delivering sustainability benefits alongside patient care and have led to the development of many of the innovations discussed within this report, and thus they should continue to be supported and developed.

Alongside SBRI Healthcare, the AAC guidance document outlines two further major public funding options, namely Innovate UK's Biomedical Catalyst programme[78] and calls by UK's largest health and care research funder, the National Institute for Health and Care Research (NIHR).[79] Previously, NIHR has made funding calls targeted at Net Zero healthcare solutions,[80] and more of these are encouraged. Outside of supporting SMEs to develop MedTech to enable the NHS to achieve its Net Zero ambition, NIHR and UK Research and Innovation (UKRI) made a joint call in 2023,[81] in which they proposed the creation of research 'hubs' that will look to address five Net Zero challenges facing healthcare.

Recommendation

Enhanced funding mechanisms, with a specific focus on sustainability challenges. Building on the Net Zero-specific initiatives led by the SBRI Healthcare programme, there is a need for more targeted calls with a focus on sustainability and increased encouragement for university involvement. Capitalising on the success of Innovate UK's Biomedical Catalyst funding, governments should consider expanding similar initiatives to further stimulate innovation.

Procurement

Linking innovative engineering companies and the healthcare facilities that they aim to supply is a complex procurement system. Even if a product has been developed in collaboration with the NHS, such as those funded by the SBRI Healthcare programme, there is no guarantee for developers that their solutions will be purchased and used within a healthcare setting.

The AAC's Navigation Tool attempts to outline the procurement routes available for prospective innovators.[76] There are five routes available, from directly selling to trusts to entering the NHS Supply Chain system, which was implemented in 2017–18 to simplify procurement in the NHS.

A National Audit Office report published in early 2024 on NHS Supply Chain's efficiency concluded that it is not fulfilling its potential and that 'its systems and processes do not work well for its customers', something NHS Supply Chain recognises.[82] A key issue faced by Supply Chain in achieving maximum value for money for the NHS is that trusts are still able to negotiate separately with suppliers, leading to variation in the prices paid by trusts for similar items.

These problems faced by trusts make procuring items a difficult process, and the experience is similar for sellers, such as the innovators profiled within this report. Just because a company has had success with providing one NHS trust with its device does not guarantee it will then have access to further providers. This uncertainty regarding procurement can take away time from developing a product, even for companies successful in programmes like SBRI Healthcare.

Funding for hospitals

A lack of funding for the NHS is a topic that regularly dominates news headlines across the UK.[83] Each hospital trust must adhere to strict capital spending limits, which means that once spending on essential activities has been allocated, many trusts have a limited budget left for sustainability-related improvements. Sustainability-specific funding opportunities, such as the Public Sector Decarbonisation Scheme,[84] offer an opportunity outside of spending limits to make sustainable improvements to healthcare practices, but they are rare and highly competitive. Indeed, a 2021 survey of 237 NHS organisations by the BMA found that less than half (46%) of organisations surveyed had received funding to spend on sustainability and decarbonisation.[23]

While the NHS's targets and ambition are commendable, major investment is required by every trust across the UK to achieve them. Some trusts, such as University College London Hospitals, have large research capabilities that generate revenue on top of regular funding. There is an argument that such institutions should be able to invest this self-generated revenue on improvements to their estate and practices that have Net Zero benefits. These hospitals could then act as proof-of-concept sites for other hospitals in the UK and demonstrate that investing in technologies that cut emissions can also have positive economic consequences through financial savings. The funding limitations discussed here make a financial benefit a 'must have' for any potential technology relating to sustainability improvements and emissions savings, alongside improvements in patient care and experience.

Government must not force NHS trusts to choose between functioning effectively and becoming more sustainable by providing protected funding for decarbonisation schemes. This will empower trusts to move towards Net Zero emissions and save money in the long term. This must be supported by strong leadership within the NHS at the executive level, which should mandate the implementation of proven sustainability measures by all trusts. Only with this dedicated financial support and clear leadership will a behaviour change and prioritisation of more sustainable practices occur.

Recommendation

Targeted Net Zero funding for hospitals. Hospitals are under extreme financial pressures, and while there is a desire to achieve Net Zero and more sustainable healthcare systems, it is not a priority given current constraints. If governments are serious about achieving sustainability goals, targeted funding for hospitals should be prioritised to empower them to improve existing equipment and implement innovative novel technologies, guided by Net Zero boards and informed by engineers. Technologies that lead to cost savings as well as environmental and patient benefits should continue to be prioritised and promoted, to increase awareness of the advantages of innovating in healthcare. Hospitals can act as test-beds for new low carbon technologies, but this needs to be supported financially and by simple procurement mechanisms.

Regulation of MedTech

In Great Britain, medical devices are regulated under the UK Medical Devices Regulations 2002,[85] which implemented a set of three EU Medical Device Directives (90/385/EEC, 93/42/EEC, 98/79/EC).[86,87,88] This means that the current route to market for a medical device developed in the UK is based on EU legislation developed over 20 years ago. In 2012, the European Commission adopted a proposal for a new set of regulations that better reflected the innovations in technology and science that had occurred since the original regulation came into force.[89,90] In the years following, the UK, in particular the Medicines and Healthcare products Regulatory Agency (MHRA), were instrumental in updating the regulations, which came into effect in 2021.[91] As these changes did not occur during the UK's post-Brexit transition period, they were not automatically retained as UK law and therefore do not apply in Great Britain (this is not the case in Northern Ireland under the terms of the Northern Ireland Protocol).[92]

As Great Britain did not adopt new EU regulations, in 2021 the MHRA launched a consultation that intends to lead to the introduction of UK-specific regulations. This process is due to result in 'core elements' of a new regulatory framework being in place by 2025.[93,94]

For a medical device to be used on the UK market, it must pass through the UK's regulatory process and obtain a UKCA (UK Conformity Assessed) marking. This is not recognised outside of Great Britain (including in Northern Ireland), and it was designed to replace the EU's CE marking for British goods.[95] Recently, the UK government announced an extension of the acceptance of the previously accepted CE marking in Great Britain, until 2028 or 2030 depending on the device type.[96] This is a welcome announcement and will allow for companies that gain the CE marking to supply their products both in the UK and the EU, although the plan for post-2030 is unclear.

The complex regulatory landscape for medical devices routinely presents significant and costly challenges for engineers and innovators looking to develop novel solutions to healthcare's sustainability crisis. This is particularly true for SMEs that may be relatively new to the market. The process can be time-consuming, and it is often cited that more stringent rules have added pressure on UK Approved Bodies and EU Notified Bodies, the organisations that grant certification of medical devices in the UK and EU.[97] While the MHRA announced three new UK Approved Bodies to certify devices,[98] waiting lists are long, and the same problem exists in Europe.

A shorter timeframe to obtain market approval and a larger market share may cause companies to turn to the US market when developing medical devices,[97] further threatening an already declining sector in the UK and EU, evidenced by the UK's FDI (foreign direct investment) in life sciences nearly halving between 2021 and 2022.[99] Additionally, some clinicians in Europe have warned of issues related to the availability of medical devices, a problem that could cause further issues in the future.[100]

For some of the engineering innovations presented within this report, the regulatory landscape is even more complex, as they are not defined as 'medical devices'. Apian, profiled in Case study 1, has faced regulatory challenges since the MHRA lacks a regulatory framework for its product.[101]

Despite current issues, the release of a new set of regulations for UK medical devices in 2025 offers an opportunity for the UK government to develop regulations which facilitate innovation while accounting for risk and aligning with regulations seen elsewhere. Significant improvements can be made in supporting companies through the regulatory process, a role filled for novel devices by the MHRA's Innovation Office, which has scope for expansion.[102] New regulations should also consider how devices that lie outside of current regulatory frameworks can be supported and not stifled, as a more constructive relationship between developers and regulators can only lead to a more fruitful innovation space in the UK.

The Department of Health and Social Care's (DHSC) 2023 'Medical technology strategy' was correct to outline that "Regulatory systems have shown their ability to respond with agility to global incidents", with 22 critical products receiving exceptional use authorisation during the Covid-19 pandemic.[103] New regulations should explore opportunities whereby the regulatory process can be accelerated in this way when innovative devices are developed that can lead to quick and sizeable wins in the NHS's journey towards Net Zero. This should also apply to procurement routes.

Finally, we welcome the pilot of the Innovative Devices Access Pathway (IDAP),[104] launched in 2023 to provide successful applicants with support through the whole regulatory process, including potentially providing early engagement with UK Approved Bodies to support UKCA marking.[105] Such schemes should become commonplace, particularly when targeting key areas such as solutions that will help healthcare move towards Net Zero.

Recommendation

A streamlined regulatory process and support for companies to navigate this. Use the current review of medical device regulations to work towards understanding current barriers and simplifying regulatory requirements for sustainability-focused innovations, learning lessons from the Covid-19 response and reducing the time it takes for innovations to get to market. New regulations should lower the regulatory burden while maintaining world-leading safety standards, which will be particularly beneficial to SMEs. The UK has an opportunity to develop an innovative and responsive regulatory system, and regulatory bodies should work with industry-led organisations like the Association of British HealthTech Industries (ABHI) to guide this development.

Workforce and skills

Embedding engineers in healthcare

"Engineers in the NHS maintain and repair a range of equipment and facilities from ambulances to dialysis machines to air conditioning units. All are vital to a high-quality NHS."[106]

This quote, taken from the NHS's website, highlights the key role of engineers within healthcare to maintain and repair the vast quantity of equipment on which modern healthcare relies. The NHS employs biomedical engineers to maintain and manage medical equipment; plant maintenance engineers to ensure water, electrical systems, and boilers are operational within healthcare units; prosthetics engineers to create and maintain artificial limbs; and building services engineers to oversee the installation and maintenance of systems within buildings. In addition to those who maintain and repair equipment and facilities, a far smaller number of engineers are employed to work on the area of novel device design in healthcare settings alongside clinical colleagues,[107] positions that we believe must be increased in number, as they are vital to the development of innovative solutions to specific conditions.

Such collaboration should extend to the top of NHS trusts, with the IMechE having previously called for each trust to employ a chief engineer to encourage best practices in procurement and oversee the maintenance and use of medical equipment.[108,109] Such a role has a renewed importance in the context of the NHS's Net Zero mission, where engineers at decision-making levels would assist trusts in making efficient and financially viable decisions on sustainability strategies by utilising technical expertise and systems-thinking approaches.

Recommendation

Facilitating engineering innovation within healthcare settings. The NHS should explore further opportunities for clinical engineers employed by the NHS to work closer with colleagues in hospitals as part of the clinical team and develop tailored solutions to Net Zero challenges. This should be supported with the provision of further roles for engineers at the decision-making level of healthcare organisations, where they can provide technical expertise and oversight to support healthcare's Net Zero transition. This is already occurring in some settings, but a consistent approach across healthcare is required.

Workforce size

Healthcare's journey towards Net Zero relies on technology. This may be through engineering innovations that tackle a particular Net Zero problem or through the installation of new, lower-emitting heat sources. In England, there are currently not enough engineers working directly in the NHS to maintain such technologies and achieve the goals of sustainability programmes in the long term. Surveys of the Medical Physics and Clinical Engineering (MPCE) workforce by the Institute of Physics and Engineering in Medicine (IPEM) support this claim. Their work revealed that the workforce must grow by 44% to function effectively and that 24% of the current MPCE workforce is close to reaching retirement age.[110]

Despite this, the MPCE profession was not mentioned in NHSE's 2023 Long Term Workforce Plan.[111,112] Recognition of clinical engineering in such publications is essential if the shortage of clinical engineers is to be addressed and the NHS is to achieve its key goals, including its Net Zero targets. Workforce planning and mandated targets for clinical engineering positions in healthcare, supported by sufficient funding and the creation of new roles where necessary, will enable clinical engineering to develop into an established and recognised profession within healthcare, leading to future benefits for the entire healthcare system.

Clinical engineers are also not currently eligible for the Health and Care Worker visa. [113] The IPEM recommends that this should be addressed, with clinical engineers added to the list to support short-term growth in the sector, which IMechE supports.

IMechE acknowledges that the number of engineers in the UK is a threat to nearly all sectors, not just healthcare, with all major engineering specialisms being listed on the Home Office's shortage occupations list.[114] Coordinated action on the part of government, professional engineering institutions (PEIs), and academia is required to increase the number of qualified engineers in the country. In healthcare, it is the responsibility of healthcare providers to work with these actors on this and provide enough high-quality engineering positions within their organisations, with a flexible array of entry routes. There is no doubt that without this action and a resulting increase in the number of engineers employed by healthcare providers, that Net Zero goals in healthcare will not be achieved.

Recommendation

Workforce planning in collaboration with professional engineering institutions to assess the current and future needs of clinical engineers within hospitals to support the integration of new technologies.

Entry routes

Engineers enter the NHS through various pathways. This includes applying for posts using an accredited engineering qualification, after which engineers can apply for the NHS Scientist Training Programme (STP). The STP provides some successful candidates with the opportunity to complete a postgraduate master's programme alongside their three-year training programme, during which they can specialise as a clinical engineer.[115]

The NHS also runs its Practitioner Training Programme (PTP), which provides clinical engineer routes for applicants.[116] Individual NHS hospitals also offer apprenticeship and training programmes at multiple levels, including some in engineering disciplines.[117]

While available routes into hospitals exist for engineers, they lack coordination and consistency across different settings, with a lack of uniform recognition of engineers within the NHS. Engineers are often assigned to non-clinical departments, operate at varying levels of authority, and have limited input into critical decision-making. The NHS should build on the popularity of the STP and PTP by boosting engineering options in such schemes, with only 10 clinical engineer posts available in the 2024 STP.[118] More generally, healthcare providers must work with academic institutions and professional bodies to promote engineering opportunities within hospitals by improving the visibility of the sector through outreach initiatives, mentoring opportunities, and learning and development courses.

Recommendation

Promoting and enhancing pathways to biomedical engineering careers through a joined-up approach to training and progression. Healthcare providers should continue to develop their apprenticeship, T-level, and training opportunities for engineers and provide attractive and uniformly recognised roles across healthcare. They should be supported by professional engineering institutions, who should work with the National School of Healthcare Science to actively promote biomedical or clinical engineering as an attractive and exciting career opportunity to implement problem-solving skills in a high-impact sector.

Sharing knowledge and success

Historically, entrenched approaches to innovation have resulted in resources being wasted on unsuitable or poorly specified devices and processes. In some cases, technology is being incorrectly used or disposed of because it fails to meet the needs of clinicians and patients.

By introducing opportunities for engineers to engage with clinicians, this behaviour can be disrupted, collaboration can be encouraged, and efficient management of technologies can be developed. With this first-hand direct insight into the challenges faced by healthcare providers, engineers can develop solutions tailored to address specific needs.

Linking the NHS to external engineering expertise

As well as creating additional jobs for engineers within healthcare organisations, further collaboration should be encouraged between engineers working in academia or industry with clinicians working in healthcare settings. This should be facilitated by healthcare providers, who should provide opportunities for engineers to engage with their staff to understand the key sustainability challenges facing their facilities and provide solutions to them. Combining engineers' technical knowledge and ability to employ systems-thinking approaches with clinicians' medical expertise is an effective method to tackle the key sustainability questions in healthcare, as demonstrated by Case study 3, where collaboration between healthcare experts and engineers has enabled the development of a ground-breaking solution to a key Net Zero challenge.

An example of how collaboration can be structured was seen in 2022, when the Health Innovation Network University College London Partners invited experts from academia and the NHS to a series of 'sandpit' events, where they were challenged to 'develop novel projects which could produce actionable evidence and break down the barriers to decarbonising the NHS estate'.[119] Following the event, a selection of submissions were selected for funding from Greener NHS. Events such as these should be explored by trusts around the UK, particularly larger ones with academic links, ensuring that industry partners are involved. Health innovation networks provide a strong framework for facilitating further events, with an opportunity to focus these events on engineering challenges. This will require funding in order to be successful as well as strong knowledge-sharing capabilities to ensure that the benefits are shared throughout the country.

King's College London is also helping to facilitate engineering innovation in healthcare by opening the London Institute for Healthcare Engineering (LIHE), the 'first MedTech venture builder in the UK'.[120] The LIHE, opening in 2024, aims to bring together academic experts, MedTech companies, and clinicians from Guy's and St Thomas' NHS Foundation Trust to ensure healthcare engineering research is rapidly translated into products used in the NHS. We acknowledge that such developments are unrealistic for most healthcare providers around the UK, but we believe that the LIHR can be used as a model of how to facilitate collaboration between academia, the healthcare sector, and industry.

Recommendation

Creation of opportunities for engineers in industry and academia to engage with healthcare settings and work alongside clinicians to gain a first-hand understanding of the challenges faced by healthcare providers and develop innovative solutions that directly address the unique needs of the healthcare sector. In the first case, this could involve sandpit events and workshops, following the example set by some health innovation networks, and supported by NHS trusts, professional engineering institutions, and universities.

Establishing the channels of communication

Once engineering solutions have been developed and trialled in one location, the sharing of best practices, lessons learned, and further collaboration will help distribute the innovation and solution between trusts. Currently, communication channels between trusts and NHS organisations are limited, so this is being hindered. There is a need for collaborative platforms, inspired by successful models like the Nordic Center for Sustainable Healthcare, to share best practices and case studies across the sector.[121]

Recommendation

Creation and implementation of a centralised knowledge-exchange platform to facilitate the seamless exchange of knowledge and best practices between hospitals and industry. This will serve as an opportunity to share success stories, lessons learned, and collaborative opportunities and prevent the duplication of efforts.

Support for industry to adopt sustainable practices

With over 60% of carbon emissions in the NHS Carbon Footprint Plus in England occurring in the supply chain, there is a significant opportunity for decarbonisation.[122] Suppliers will only be able to qualify for NHS contacts if they comply with the NHS Net Zero Roadmap.[123] In April 2024, a tiered approach will be introduced. A full Carbon Reduction Plan (CRP) will be required for high-value contracts (£5m per annum), and a Net Zero commitment will be required for lower-value contracts.[124] Since April 2022, there has been a requirement to provide a CRP or Net Zero commitment in addition to a minimum 10% weighting on Net Zero and social value in NHS procurements.

The diversity of industries and sectors contributing to the supply chain, each with a unique set of processes, technologies, and environmental impacts, adds to the challenge of decarbonisation. These challenges are not solely technological but also involve reshaping established practices, fostering innovation, and navigating the potential disruptions and opportunities that accompany the transition to a low-carbon supply chain across all four UK health services. Engineers have a duty to ensure that the businesses they work for are preparing themselves for the sustainability requirements of healthcare providers and ensuring that their green credentials are clear for all to see.

Consistent monitoring and reporting across the supply chain will be critical to ensure accountability and encourage transparency. To allow for this, adherence to established standards and benchmarks will be essential. There is a concern from industry that the responsibility and pressures will be shifted down the supply chain and onto SMEs, many of which will not be able to navigate or afford the monitoring and reporting requirements. Education and awareness campaigns are needed to support these companies in understanding the appropriate systems and processes to effectively measure carbon emissions and to increase their understanding of social value.

Moreover, the NHS providers across the UK, which are already under substantial pressure, require effective emission measurements and compliance monitoring. The implementation of robust mechanisms involving regular assessments, audits, and reporting obligations is essential.

Recommendation

Incentivising sustainability practices in the supply chain. While it is right to question the impact of supply chains as identified in the Net Zero Supplier Roadmap, it needs to be done in a considered, supported, and practical manner to ensure responsibility is not shifted down the supply chain. The NHS should continue to work collaboratively with industry representatives, such as the ABHI, to understand the underlying challenges to decarbonising the supply chain and develop consistent monitoring practices and tools across the supply chain to encourage engagement, such as the Evergreen Sustainable Supplier Assessment.

Recommendation

Emission measurements and compliance monitoring. With the NHS already under pressure, consideration of effective emission measurements and compliance monitoring is needed. Ideally, robust mechanisms, involving regular assessments, audit, and reporting obligations would be implemented. The NHS should work with industry and the National Measurement Laboratories to consider the practicalities of monitoring.

Public support for green initiatives and technologies

Support for and awareness of the impact of the healthcare sector on the environment is diminishing. Recent polling of public perceptions of health and social care conducted by the Health Foundation and Ipsos showed that while most (61%) people think the NHS is not well prepared for climate impacts,[125] there is limited understanding of the impact of healthcare on the environment, with only 19% of respondents agreeing that the NHS contributed to climate change.[126] The public is also less likely than in previous years to agree that the NHS has a responsibility to reduce its impact on climate change, and support for the NHS's Net Zero ambition has dropped to 60%. As the case studies in this report illustrate, there are many co-benefits to switching to more sustainable options, and often patient outcomes and experiences can be improved and costs reduced. Government, healthcare providers, and clinicians should help to highlight these benefits to increase support. Demand from the public for a better and more sustainable healthcare service will add momentum to achieving the targets set.

Public support is also needed for the adoption of new technologies that can help support treatment, prevent illness, enable early diagnosis, and empower health management. A survey conducted by NHS Confederation and Google Health found that many individuals are not confident about using technology to manage their health and have a fear they may be locked out of healthcare if they cannot access or use digital tools.[127] Health services should help patients, carers, and the public understand how they benefit from technologies and design services with patients to empower them and support user uptake.

Recommendation

Development of a UK-wide strategy, linking the ongoing environmental crisis to patient care, placing the environment and patient outcomes at its core. This strategy should emphasise the interconnection between climate change and health, the need for urgent solutions, and the importance of technology acceptance by patients.

Recommendation

A public awareness campaign is essential to address the declining support and awareness of the impact of the healthcare sector on the environment and support the uptake of new technologies. This could include sharing with patients details on the carbon footprint of the care they receive.

References

1 Health Care Without Harm. (2019). *Health Care's Climate Footprint: How the Global Health Sector Contributes to the Global Climate Crisis and Opportunities for Action.*

2 World Health Organization (WHO). (2023). *Leaders spotlight the critical intersection between health and climate ahead of COP-28 first ever Health Day.* Available at: https://www.who.int/news/item/18-09-2023-leaders-spotlight-the-critical-intersection-between-health-and-climate-ahead-of-cop-s-first-ever-health-day

3 United Nations (UN). (2022). *Historical and updated classification of developed and developing regions (May 2022).* Available at: https://unstats.un.org/unsd/methodology/m49/historical-classification-of-developed-and-developing-regions.xlsx

4 National Health Service (NHS) England. (2022). *Delivering a 'Net Zero' National Health Service- July 2022.*

5 Health and Care Act 2022. Available at: https://www.legislation.gov.uk/ukpga/2022/31/contents/enacted

6 Scottish Government. (2022). *NHS Scotland: Climate Emergency & Sustainability Strategy 2022-2026.*

7 Carbon Trust. (2021). *NHS Wales Decarbonisation Strategic Delivery Plan 2021-2030.*

8 WHO Regional Office for Europe. (2017). *Environmentally sustainable health systems: a strategic document. Copenhagen: WHO Regional Office for Europe.*

9 Intergovernmental Panel on Climate Change (IPCC). (2023). *Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC: Geneva, pp. 1-34. doi: 10.59327/IPCC/AR6-9789291691647.001

10 Lynas, M., Houlton, B. Z., and Perry, S. (2021). 'Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature', *Environmental Research Letters,* 16(11). doi: 10.1088/1748-9326/ac2966

11 Ghebreyesus, T. A., Al Jaber, S. A., and Kerry, V. (2023). *We must fight one of the world's biggest health threats: climate change.* Available at: https://www.who.int/news-room/commentaries/detail/we-must-fight-one-of-the-world-s-biggest-health-threats-climate-change

12 UN. (n.d.). *Climate change recognized as 'threat multiplier', UN Security Council debates its impact on peace.* Available at: https://www.un.org/peacebuilding/fr/news/climate-change-recognized-%E2%80%98threat-multiplier%E2%80%99-un-security-council-debates-its-impact-peace

13 WHO. (2023). *Climate change.* Available at: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

14 Met Office. (2022). *Joint hottest summer on record for England.* Available at: https://www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2022/joint-hottest-summer-on-record-for-england

15 UK Health Security Agency (UKHSA). (2022). *Heat mortality monitoring report: 2022.* Available at: https://www.gov.uk/government/publications/heat-mortality-monitoring-reports/heat-mortality-monitoring-report-2022

16 Office for National Statistics (ONS) and UKHSA. (2022). *Excess mortality during heat-periods: 1 June to 31 August 2022.* Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/excessmortalityduringheatperiods/englandandwales1juneto31august2022

17 Public Health England. (2018). *Health matters: air pollution.* Available at: https://www.gov.uk/government/publications/health-matters-air-pollution/health-matters-air-pollution#:~:text=Poor%20air%20quality%20is%20the,leading%20to%20reduced%20life%20expectancy

18 UKHSA. (2022). *Chemical Hazards and Poisons Report Issue 28*- June 2022.

19 Public Health England. (2018). *Estimation of costs to the NHS and social care due to the health impacts of air pollution: summary report.* London: Public Health England.

20 House of Commons Science, Innovation and Technology Committee. (2023). *Oral evidence: Emerging diseases and learnings from covid-19, HC 1303*. Available at: https://committees.parliament.uk/oralevidence/13271/pdf/

21 Centre for Disease Control and Prevention. (n.d.). *Our Risk for Infectious Diseases is Increasing because of Climate Change.*

22 Department of Health and Social Care (DHSC). (2021). *UK health services make landmark pledge to achieve net zero.* Available at: https://www.gov.uk/government/news/uk-health-services-make-landmark-pledge-to-achieve-net-zero

23 British Medical Association (BMA). *More support needed to help the NHS reach net zero.* Available at: https://www.bma.org.uk/what-we-do/population-health/protecting-people-from-threats-to-health/more-support-needed-to-help-the-nhs-reach-net-zero

24 The Guardian. (2023). *Revealed: only 10 of Boris Johnson's promised 40 new hospital projects have planning permission.* Available at: https://www.theguardian.com/society/2023/feb/04/only-10-of-boris-johnson-promised-40-new-hospitals-have-full-planning-permission

25 The Guardian. (2023). *Four in 10 NHS hospitals in England found to use outdated equipment in Lib Dem study.* Available at: https://www.theguardian.com/society/2023/mar/20/four-in-10-nhs-hospitals-in-england-found-to-use-outdated-equipment-in-lib-dem-study

26 Scottish Government. (2021). *A Policy for NHS Scotland on the Climate Emergency and Sustainable Development – DL (2021) 38.* Available at: https://www.publications.scot.nhs.uk/files/dl-2021-38.pdf

27 *The Climate Change Act 2008 (2050 Target Amendment) Order 2019.* Available at: https://www.legislation.gov.uk/uksi/2019/1056/contents/made

28 Institution of Mechanical Engineers. (2022). *Engineering a Net Zero energy system.*

29 Institution of Mechanical Engineers. (2023). *IMechE Strategy 2030: Global, inclusive and digitally enabled.* Available at: https://imeche.shorthandstories.com/c93a3e37-0f9b-416d-97de-a3d1723656ce/

30 National School of Healthcare Science. (2024). https://nshcs.hee.nhs.uk/healthcare-science/healthcare-science-specialisms-explained/physical-sciences/clinical-engineering/

31 NHS England. (2022). *NHS Net Zero Building Standard.* Available at: https://www.england.nhs.uk/estates/nhs-net-zero-building-standard/

32 Nesta. (2022). *How to scale a highly skilled heat pump industry.*

33 Brooks, K., Landeg, O., Kovats, S., Sewell, M., and O'Connell, E. (2023). 'Heatwaves, hospitals and health system resilience in England: a qualitative assessment of frontline perspectives from the hot summer of 2019', *BMJ Open,* 13(3). doi: 10.1136/bmjopen-2022-068298

34 Picciochi, M., Glasbey, J. C., Li, E., Kamarajah, S. K., Nepogodiev, D., Simoes, J. FF and Bhangu, A. (2023). 'Elective surgical services need to start planning for summer pressures, *British Journal of Surgery,* 110(4), pp. 508-510. doi: 10.1093/bjs/znad003

35 Department for Environment, Food and Rural Affairs. (2023). *The Third National Adaptation Programme (NAP3) and the Fourth Strategy for Climate Adaptation Reporting.*

36 NHS England. (2023). *Net Zero travel and transport strategy.*

37 Institution of Mechanical Engineers. (2023). *UK Automotive Sector: Surviving the Net Zero Transition.*

38 Healthwatch. (2019). *There and back – What people tell us about their experiences of travelling to and from NHS services.*

39 Purohit, A., Smith, J. and Hibble, A. (2021). 'Does telemedicine reduce the carbon footprint of healthcare? A systematic review', *Future Healthcare Journal,* 8(1), e85-e91. doi: 10.7861/fhj.2020-0080

40 Neve, G., Fyfe, M., Hayhoe, B. and Kumar, S. (2020). 'Digital health in primary care: risks and recommendations', *British Journal of General Practice,* 70(701), pp. 609-610. doi: 10.3399/bjgp20X713837

41 NHS England. (2023). *NHS clinical waste strategy.*

42 Leung, L. W. M., Evranos, B., Grimster, A., Li, A., Norman, M., Bajpai, A., Zuberi, Z., Sohal, M., et al. (2019). 'Remanufactured circular mapping catheters: safety, effectiveness and cost', *Journal of Interventional Cardiac Electrophysiology,* 56, pp. 205-211. doi: 10.1007/s10840-018-0497-x

43 NHS England. (n.d.). *Device remanufacture 'how to' guide.* Available at: https://www.lpp.nhs.uk/media/477394/Device-Remanufacturing-How-to-Guide-ppt.pdf

44 DHSC. (2023). *Medical technology strategy.*

45 Small Business Research Initiative (SBRI): Healthcare. (n.d.) Available at: https://sbrihealthcare.co.uk/

46 Apian. (n.d.). *Company.* Available at: https://www.apian.aero/about

47 NHS England. (n.d.). *Clinical entrepreneur programme.* Available at: https://www.england.nhs.uk/aac/what-we-do/how-can-the-aac-help-me/clinical-entrepreneur-programme/

48 SBRI Healthcare. (2023). *Patients to benefit from 18 pioneering innovations that also accelerate a greener NHS.* Available at: https://sbrihealthcare.co.uk/news/patients-to-benefit-from-18-pioneering-innovations-that-also-accelerate-a-greener-nhs

49 Apian. (n.d.). *Solent NHS drone trials.* Available at: https://www.apian.aero/solent

50 Apian. (n.d.). *Northumbria: NHS drone trials – Stage 1.* Available at: https://www.apian.aero/northumbria-stage-1

51 Fu, E. (n.d.). *The sustainability of Zipline's autonomous aerial logistics.* Zipline.

52 Civil Aviation Authority and Department for Transport. (2023). *Airspace Modernisation Strategy 2023-2040.*

53 BBC News. (2023). *Northumberland NHS drone trial 'massive airspace grab'.* Available at: https://www.bbc.co.uk/news/uk-england-tyne-66742698

54 Walk With Path. (n.d.). *Path Feel. A simple solution to improve balance and reduce the risk of ulcers.* Available at: https://www.walkwithpath.com/pages/path-feel-coming-soon

55 Diabetes UK. (n.d.). *Diabetic neuropathy (nerve damage).* Available at: https://www.diabetes.org.uk/guide-to-diabetes/complications/nerves_neuropathy#:~:text=signs%20of%20neuropathy.-,Diabetic%20peripheral%20neuropathy,neuropathy%2C%20sensory%20neuropathy%20or%20both

56 Singh, N., Armstrong, D. G. and Lipsky, B. A. (2005). *'Preventing foot ulcers in patients with diabetes', Clinical Review,* 293(2), pp. 217-228. doi: 10.1001/jama.293.2.217

57 Snyder, R. J., Cardinal, M., Dauphinée, D. M. and Stavosky, J. (2010). 'A post-hoc analysis of reduction in diabetic foot ulcer size at 4 weeks as a predictor of healing by 12 weeks', *Ostomy Wound Management,* 56(3).

58 Naemi, R., Chockalingam, N., Lutale, J. K. and Abbas, Z. G. (2020). 'Predicting the risk of future diabetic foot ulcer occurrence: a prospective cohort study of patients with diabetes in Tanzania', *BMJ Open Diabetes Research and Care,* 8(1). doi: 10.1136/bmjdrc-2019-001122

59 NHS Digital. (2022). *National Diabetes Foot Care Audit (NDFA) internal review: July 2014-March 2021.*

60 Armstrong, D. G., Swerdlow, M. A., Armstrong, A. A., Conte, M. S., Padula, W. V. and Bus, S. A. (2020). 'Five year mortality and direct costs of care for people with diabetic foot complications are comparable to cancer', Journal of Foot and Ankle Research, 13(16). doi: 10.1186/s13047-020-00383-2

61 Askey, A., Gadsby, R., Harrington, A. and Jeffcoate, W. (2020). 'Do you refer all newly occurring foot ulcers for specialist assessment within one working day?', *Diabetes & Primary Care,* 22(1), pp. 7-8.

62 Kerr, M., Barron E., Chadwick, P., Evans, T., Kong, W. M., Rayman, G., Sutton-Smith, M., Todd, G., *et al.* (2019). 'The cost of diabetic foot ulcers and amputations to the National Health Service in England', *Diabetic Medicine,* 36(8), pp. 995-1002. doi: 10.1111/dme.13973

63 Steer. (2022). *An Evaluation of the Small Business Research Initiative.*

64 Centre for Sustainable Healthcare. (n.d.). *The Nitrous Oxide Project.* Available at: https://sustainablehealthcare.org.uk/what-we-do/sustainable-specialties/anaesthetics/nitrous-oxide-project

65 NHS England. (2023). *Guidance on minimising time weighted exposure to nitrous oxide in healthcare settings in England.* Available at: https://www.england.nhs.uk/long-read/guidance-on-minimising-time-weighted-exposure-to-nitrous-oxide-in-healthcare-settings-in-england/

66 Chakera, A. (2021). *Evidence-based policy report: reducing environmental emissions attributed to piped nitrous oxide products within NHS hospitals.*

67 NHS Scotland Assure. (2023). *Technical update issue 1: Entonox® System Loss Mitigation and Management.*

68 Vallejo, M. C. and Zakowski, M. I. (2019). 'Pro-con debate: nitrous oxide for labor analgesia', *BioMed Research International.* doi: 10.1155/2019/4618798

69 Abbasi, K., Ali, P., Barbour, V., Benfield, T., Bibbins-Domingo, K., Hancocks. S., Horton, R., Laybourn-Langton, L., et al. (2023). 'Time to treat the climate emergency and nature crisis as one indivisible global health emergency', *BMJ,* 383, p. 2355. doi: 10.1136/bmj.p2355

70 European Environment Agency. (2021). *Impact of COVID-19 on single-use plastic and the environment in Europe.*

71 Rizan, C., Reed, M. and Bhutta, M. F. (2021). 'Environmental impact of personal protective equipment distributed for use by health and social care services in England in the first six months of the COVID-19 pandemic', *Journal of the Royal Society of Medicine,* 114(5). doi: 10.1177/01410768211001583

72 Health Care Without Harm. (2021). *The role of chemistry in sustainable medical textiles.*

73 YouTube. (2023). *Revolution ZERO Cornwall Iso8 Decontamination Unit September 2023.* Available at: https://www.youtube.com/watch?v=KU0iVagxMI4

74 UK Research and Innovation. (2023). *FOI2023/00234: biomedical catalyst success rates.* Available at: https://ukri.disclosurelog.co.uk/case/8bd630fa-d08b-4086-8779-a5b7e92712ad

75 SBRI Healthcare. (2022). *SBRI Healthcare Annual Review 2020-2022.*

76 Accelerate Access Collaborative (AAC). (2023). *Health Technology Pathway: navigation tool for innovators in England.* Available at: https://www.england.nhs.uk/aac/wp-content/uploads/sites/50/2023/04/aac005a-health-technology-pathway-map.pdf

77 SBRI Healthcare. (n.d.). *SBRI healthcare closed competitions.* Available at: https://sbrihealthcare.co.uk/competitions/overview?cat=closed-competitions

78 Innovate UK. (n.d.). *Biomedical catalyst.* Available at: https://iuk.ktn-uk.org/programme/biomedical-catalyst/

79 National Institute for Health and Care Research (NIHR). (n.d.). Available at: https://www.nihr.ac.uk/

80 NIHR. (2022). *Delivering a sustainable health and care system – specification document.* Available at: https://www.nihr.ac.uk/documents/delivering-a-sustainable-health-and-care-system-specification-document/29647

81 UK Research and Innovation (UKRI). (2023). *Realising the health co-benefits of the transition to net zero.* Available at: https://www.ukri.org/opportunity/realising-the-health-co-benefits-of-the-transition-to-net-zero/

82 National Audit Office. (2024). *NHS supply chain and efficiencies in procurement.*

83 British Medical Association. (2023). *Health funding data analysis.* Available at: https://www.bma.org.uk/advice-and-support/nhs-delivery-and-workforce/funding/health-funding-data-analysis#:~:text=Although%20NHS%20spending%20has%20increased,and%20some%20estates%20are%20unsafe

84 Department for Energy Security and Net Zero. (2020). *Public sector decarbonisation scheme.* Available at: https://www.gov.uk/government/collections/public-sector-decarbonisation-scheme

85 *The Medical Devices Regulations 2002.* Available at: https://www.legislation.gov.uk/uksi/2002/618/contents/made

86 European Council. (1990). *Council Directive 90/385/EEC of 20 June 1990 on the approximation of the laws of the Member States relating to active implantable medical devices.* OJ L 189, 20.7.1990, p. 17.

87 European Council. (1993). *Council Directive 93/42/EEC of 14 June 1993 concerning medical devices.* OJ L 169, 12.7.1993, p. 1.

88 European Council. (1998). *Directive 98/79/EC of the European Parliament and of the Council of 27 October 1998 on in vitro medical devices.* OJ L 331, 7.12.1998, p. 1.

89 European Commission. (2012). *Proposal for a regulation of the European Parliament and of the Council on in vitro diagnostic medical devices.*

90 Deloitte. (2016). *Preparing for the future: The new European Union medical devices regulation.*

91 The European Parliament and the Council of the European Union. (2017). *Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices, amending Directive 2001/83/EC, Regulation (EC) No 178/2002 and Regulation (EC) No 1223/2009 and repealing Council Directives 90/385/EC and 93/42/EEC.*

92 UK Government. (2022). *Northern Ireland Protocol Bill.*

93 Medicines & Healthcare products Regulatory Agency (MHRA). (2024). *Implementation of the future regulations.* Available at: https://www.gov.uk/government/publications/implementation-of-the-future-regulation-of-medical-devices/implementation-of-the-future-regulations

94 MHRA. (2024). *Roadmap towards the future regulatory framework for medical devices.*

95 MHRA. (2020). *Regulating medical devices in the UK.* Available at: https://www.gov.uk/guidance/regulating-medical-devices-in-the-uk#ukcamark-and-conformity-assessment-bodies

96 MHRA. (2024). *Implementation of the future regulations.* Available at: https://www.gov.uk/government/publications/implementation-of-the-future-regulation-of-medical-devices/implementation-of-the-future-regulations

97 Beddoe-Rosendo, J., Heaysman, C. L., Hajnal, J. V., Ourselin, S. and Vanhoestenberghe, A. (2023). 'Medical device regulatory challenges in the UK are affecting innovation and its potential benefits', *Proceedings of the Institution of Mechanical Engineers, Part H: Journal of Engineering in Medicine,* 237(11). doi: 10.1177/09544119231203

98 MHRA. (2023). *Three new UK approved bodies to certify medical devices announced by the MHRA.* Available at: https://www.gov.uk/government/news/three-new-uk-approved-bodies-to-certify-medical-devices-announced-by-the-mhra

99 Department for Science, Innovation & Technology, Department of Health & Social Care and Office for Life Sciences. (2023). *Life sciences competitiveness indicators 2023.*

100 Biomedical Alliance in Europe. (2023). *Clinicians concerned about limited availability of medical devices. Report of the BioMed Alliance survey conducted in cooperation with ESC and EFORT.*

101 Regulatory Horizons Council. (2024). *The role of regulation in supporting scaling-up.*

102 MHRA. (n.d.). *MHRA Innovation Office.* Available at: https://www.gov.uk/government/groups/mhra-innovation-office

103 DHSC. (2023). *Medical technology strategy.*

104 MHRA. (2023). *The Innovative Devices Access Pathway (IDAP) – pilot phase.* Available at: https://www.gov.uk/government/publications/the-innovative-devices-access-pathway-idap/the-innovative-devices-access-pathway-idap-pilot-phase

105 MHRA. (2023). *IDAP pilot application guidance.* Available at: https://www.gov.uk/government/publications/the-innovative-devices-access-pathway-idap/idap-pilot-application-guidance#ukca-status

106 NHS England. (n.d.). *Engineer.* Available at: https://www.healthcareers.nhs.uk/explore-roles/wider-healthcare-team/roles-wider-healthcare-team/estates-services/engineer

107 NHS England. (n.d.). *Clinical engineering.* Available at: https://nshcs.hee.nhs.uk/healthcare-science/healthcare-science-specialisms-explained/physical-sciences/clinical-engineering/

108 Institution of Mechanical Engineers. (2016). *Healthcare: engineering solutions for the NHS.*

109 Institution of Mechanical Engineers. (2020). *Healthcare solutions: elevating the engineering workforce.*

110 Institute of Physics and Engineering in Medicine (IPEM). (2023). *Official IPEM statement: UK medical physics and clinical engineering workforce shortage requires urgent action.*

111 NHS England. (2023). *NHS Long Term Workforce Plan.*

112 IPEM. (2023). *Thirty years to reach staff levels required – NHS workforce plan fails to tackle the needs of medical physics and clinical engineering.* Available at: https://www.ipem.ac.uk/news/thirty-years-to-reach-staff-levels-required-nhs-workforce-plan-fails-to-tackle-the-needs-of-medical-physics-and-clinical-engineering/

113 GOV.UK. (n.d.). *Health and care worker visa.* Available at: https://www.gov.uk/health-care-worker-visa/your-job

114 UK Visas and Immigration. (2023). *Skilled Worker visa: shortage occupations.* Available at: https://www.gov.uk/government/publications/skilled-worker-visa-shortage-occupations/skilled-worker-visa-shortage-occupations

115 NHS England. (n.d.). *Scientist Training Programme.* Available at: https://nshcs.hee.nhs.uk/programmes/stp/

116 NHS England. (n.d.). *About the Practitioner Training Programme.* Available at: https://nshcs.hee.nhs.uk/programmes/ptp/about-the-ptp-programme/?_gl=1*vp-6kpa*_ga*MTQ1NTI4MTIxOC4xNzA1NDEzMTUw*_ga_1D-CLQVRTJK*MTcwNTQxNDk2My4yLjEuMTcwNTQxNTIxMi-4wLjAuMA..&_ga=2.177996000.496341940.1705413150-1455281218.1705413150

117 NHS England. (n.d.). *NHS apprenticeships – see what you could do.* Available at: https://www.healthcareers.nhs.uk/career-planning/study-and-training/nhs-apprenticeships/nhs-apprenticeships-see-what-you-could-do

118 NHS England. (2024). *STP 2024 post numbers by speciality and region.* Available at: https://nshcs.hee.nhs.uk/programmes/stp/applicants/stp-2024-post-numbers-by-specialty-and-region/

119 UCL Partners Health Innovation. (n.d.). *UCLPartners Climate Collaborative – connecting for change to help achieve NHS net zero.* Available at: https://uclpartners.com/project/uclpartners-climate-collaborative-connecting-for-change-to-help-achieve-nhs-net-zero/

120 King's College London. (n.d.). *The London Institute for Healthcare Engineering.* Available at: https://www.kcl.ac.uk/bmeis/london-institute-for-healthcare-engineering

121 Nordic Center for Sustainable Healthcare. (n.d.). Available at: https://nordicshc.org/

122 NHS London Procurement Partnership. (n.d.). *Supply chain.* Available at: https://www.lpp.nhs.uk/categories/sustainability-social-value/sustainability/supply-chain/#:~:text=61%25%20(18.9%20million%20tonnes),a%20significant%20opportunity%20for%20decarbonisation

123 NHS England. (n.d.). *Suppliers*. Available at: https://www.england.nhs.uk/greenernhs/get-involved/suppliers/

124 NHS England. (2023). *Carbon reduction plan and net zero commitment requirements for the procurement of NHS goods, services and works.* Available at: https://www.england.nhs.uk/long-read/carbon-reduction-plan-requirements-for-the-procurement-of-nhs-goods-services-and-works/

125 The Health Foundation. (2023). *Public perceptions of health and social care (May 2023).*

126 The Health Foundation. (2023). *Net zero NHS: what does the public think?* Available at: https://www.health.org.uk/news-and-comment/blogs/net-zero-nhs-what-does-the-public-think#:~:text=The%20public%20is%20less%20likely,disagree%20(up%20from%2021%25)

127 NHS Confederation. (2023). *Patient empowerment: what is the role of technology in transforming care?* Available at: https://www.nhsconfed.org/publications/patient-empowerment-what-role-technology-transforming-care#:~:text=Many%20individuals%20are%20not%20confident,confident%20in%20using%20them%20now

Institution of
MECHANICAL
ENGINEERS

One Birdcage Walk
Westminster
London SW1H 9JJ

+44 (0)20 7304 6877
media@imeche.org
facebook.com/imeche
twitter.com/imeche

www.imeche.org